SCIENCE

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APPLIED SCIENCE IN THE NAVY.

Among the technical reports issued from the Government Press, just now, those coming from the departments of the government most active in the war with Spain are of special interest. That of the Chief of the Bureau of Steam Engineering of the Navy Department, Com. G. W. Melville, is now published, and, though brief and businesslike, gives some interesting information of a more or less scientific nature, as well as of a kind to interest the average citizen in a more general way.

The first effect of the demand upon the Department for preliminary work was to 'demonstrate in the briefest and most vigorous manner the necessities, facilities and deficiencies' of the naval establishment. Fortunately, as it proved, the already established policy of keeping at the navy yards ample stocks of material and stores reduced enormously the risks and delays, embarrassments and dangers of a sudden call for active service of every available ship and gun. Much was necessarily done, however, before satisfactory provision could be made for all emergencies; yet it will never be forgotten that the navy never failed when called upon.

Some work was performed with marvellous despatch. Thus, the old and worn-out 'shell boilers' of the monitors *Manhattan*, *Mahopac* and *Canonicus*, at League Island, were replaced by new constructions in

thirty days. The new water-tube boilers were passed, in parts, through the hatches and the old boilers were cut in pieces below and passed up in small sections; thus saving the time, cost and risks of destruction and reconstruction of the decks which would have been necessary had the old types of boiler and ways of doing work been adopted. This necessity had been foreseen and provided for before the war actually began, and a provisional contract with the only firm known to be ready and able to undertake the task had been made. In five hours after the contract was signed the work had been commenced. The performance of these ships with the new boilers excelled the best work with the old.

The most tremendous work, in kind and quantity, was that of fitting out the auxiliary fleet of more than a hundred ships, of all sizes, kinds and duties, from tugs and ferryboats to ocean-steamers from the trans-atlantic lines. All were necessarily extensively altered to adapt them to their new duties, and the provision of stores, already alluded to, proved an essential element of success in securing their services promptly upon the outbreak of war. Even floating machine-shops to make repairs in the midst of the fleets were sent out and proved of inestimable value.

"There was a remarkable absence of casualty in the machinery departments of the vessels of the fighting fleet during the war. Even in action, when forced-draught conditions were in operation and the excitable natures of the men most wrought upon by the surroundings, the reports show that the machinery not only worked well generally, but that in no case was it greatly distressed. This is as fine a comment upon the personnel as upon the machinery." The statement does not apply to the torpedo-boats, the condition of which, under circumstances of operation entirely unintended in their construction, 'can only be described as horrible—boilers were burnt, cylinder-covers broken, piston and valves stuck, everything in bad shape.' This was due to absence of expert and professional supervision and to employment on duty for which these craft are not intended and for which they are unfit. No member of the Naval Engineer Corps could be spared to care for them, and the inexperienced and the inexpert young officers in charge of the boats could not be expected to succeed in keeping their machinery in order.

The amount of work performed by this Bureau, in designing new machinery, in refitting old, in construction at the navy yards and in repairs of ships, can only be realized on reading in detail the full report. Over four millions of pounds of iron and steel passed under inspection and were shipped to points at which this material was needed. All specifications and methods of inspection and test have been revised; including physical, chemical and mechanical methods and limitations of quality. Nickel-steel has been made an important and useful material for engine-construction; steel tubes are now made without weld and wonderfully perfect. New methods of shaping and welding parts give hitherto unapproachable security in use. Steel containing an unusually high proportion of carbon is now found applicable to even steam-boiler construction. Tenacities exceeding 74,000 pounds per square-inch are attained, with extensions rising above 21 per cent., and with elastic limits above 40,000 pounds. Such gains allow reduction of sizes and parts and, still more important, in a battle-ship, diminution of weights.

Water-tube boilers are unqualifiedly approved for naval purposes, and experience with those of the *Marietta*, while accompanying the *Oregon* on the long 14,000-mile voyage around Cape Horn, proves the reliability of such boilers when properly made and handled. The experience confirms the

results of test in foreign navies also. Nearly all naval vessels, at home and abroad, now include in their specifications the water-tube boiler. "The tactical importance of water-tube boilers has been emphasized by the conditions which obtained in the blockade at Santiago and the great victory of July 3d. It was necessary, for a long period, that our ships should be ready to develop maximum power at a few minutes' notice; and with cylindrical boilers this involved keeping all the boilers under steam, with heavily banked fires and a large attendant consumption of coal. Water-tube boilers of the proper kind, which admit of the rapid raising of steam with safety, remove this difficulty and give the commanding officer a more complete command of his fighting machine." Giving great power with small weight, this modern apparatus of power-production is coming into use on all torpedo boats and, as a rule, on even the heavy battle-ships.

The steam turbine is referred to, but with the statement that it is not yet certain that it will find permanent place in the naval service.

The use of oil-fuels is pronounced promising in some naval work where costs of fuel are not of prime importance. Success is met with in the use of an oil of S. G. 0.85 to 0.87, a flash-point of 315° Fahr., and a burning point of 350° Fahr. This oil is entirely safe on shipboard.

Referring to the marvellous performance of the *Oregon*, her long voyage, perfect condition at its end, and later effective action with the squadron off Santiago, a record 'which has never been equaled in the history of navies,' and attributing this fact to the admirable work of designers and constructors, and still more, if possible, to the splendid character of the personnel of the engineer department of the ship, the Engineer-in-Chief says: "For the past ten years it has been my duty and a sad one to call attention to the urgent need of a reorganization of the personnel of the Engineer Corps." Its enlargement, provision for proper selection of its officers and professional training, and of suitable inducements to men of talent and genius in this branch to enter the corps, are vitally important and necessary amendments to existing provisions for its support. An efficient Engineer Corps is as essential to the efficiency of the navy as good war-engines. The engineer and his war-engine together make victories like those of Manila and of Santiago possible, with the no less essential aid of good 'men behind the guns.' The whole department is one of applied science of the most extensive and imposing character and an Engineer Corps, scientifically educated and systematically trained to its peculiarly exacting and responsible work, is the most pressing need of the 'new navy.' The report, and its conclusion regarding the lessons of the war, is most instructive from both scientific and the political standpoints.

R. H. THURSTON.

REPORT ON THE STATE OF THE MATHEMATICAL THEORY OF ELECTRICITY AND MAGNETISM.

IN considering the state of the mathematical theory of electricity and magnetism at the end of the first half-century of the existence of this Association, it seems hardly possible to avoid a comparison with the state of affairs at the beginning of that period. In 1848, strange as the statement may seem, most of the great discoveries in electricity had been made. Coulomb had by his remarkable quantitative experiments with the torsion-balance and the proof-plane set the law of inverse squares once for all upon its feet, and thus opened the way for the wonderful applications of the analysis of Laplace, Poisson, Gauss and Green. The experimental discovery by Oersted of

the action of the electric current upon the magnetic needle had aroused the enthusiasm of Ampère, with the result of the swift production of his discovery of the laws of electrodynamics and their representation in mathematical form, by a process of reasoning characterized by Maxwell as 'perfect in form and unassailable in accuracy.' Within the next decade Faraday and Henry had independently discovered the phenomena of induction, and thus completed, with two exceptions, the list of epoch-making discoveries in the science. We may remark in parenthesis that the dynamo and the electric motor, which have wrought such a change in our city and Association in very recent years, were thus possible before the birth of the Association.

Not only had the quantitative laws of induction of currents been formulated by Faraday, but they had been obtained by a remarkable mathematical process by Neumann, using the then hardly recognized principle of the Conservation of Energy. The mathematical theory of the subject was accordingly in a well advanced state fifty years ago. It is to be noticed, however, that all the work then done had been on the basis of action at a distance, the existence of which was then unquestioned by mathematical physicists.

Not so, however, by that prince of experimental philosophers, Michael Faraday. Not less important for the theory of electricity than his discovery of current induction were his electro-statical researches by which he first showed that the forces between electrically charged bodies were not independent of the surrounding medium. Thus Faraday was led to concentrate his attention upon the medium instead of upon the charges themselves, and daringly to attack the notion of action at a distance. In order to clothe his ideas in an intuitional geometrical form, Faraday introduced the idea of physical lines of force, an idea that was long in having its fruitfulness recognized by others.

It was not until 1861 that the note was struck which has produced such a remarkable change in the theory of fifty years since. In Maxwell's papers on 'Physical Lines of Force' in the *Philosophical Magazine* of that year he gave Faraday's ideas a mathematical garb, and introduced to the mathematical world the theory that the energy was resident in the medium, rather than in the charged bodies. In 1865 appeared in the *Philosophical Transactions* Maxwell's chef-d'œuvre, the elaborate development of his ideas in his paper on 'A Dynamical Theory of the Electromagnetic Field.' Here we find for the first time the application of Lagrange's dynamical equations to obtain in a systematic and logical way the laws of electricity and its connection with magnetism. Besides the notion of the localization of energy, both electric and magnetic, in the medium, we find the other idea, foreign to the old theory, of the magnetic action due to time-variations of the electric field, these variations being termed by Maxwell displacement currents. It is not a little remarkable that Faraday had considered the possible changes taking place in the electrical state of the dielectric medium by changes of the magnetic field, and had attempted to make them experimentally evident, but without success. Whether Faraday contemplated the effect of the changes of the electrical state on the magnetic field I am not able to state. At any rate the introduction of this hypothetical magnetic effect of the displacement currents by Maxwell gave rise to a hitherto unlooked-for possibility, namely, the establishment of an electro-magnetic theory of light. This theory not only enjoyed the advantage of novelty, but was free from the fundamental difficulties of the previous dynamical theories of light, in that in it no longitudinal wave appeared.

If Maxwell's theory was true, then experimenters should discover the magnetic effect of the displacement current. We may well imagine that for many years investigators were devising means to accomplish this result; but if this was so, they were not rewarded by success. However, a crucial question had been agitated, for, according to Maxwell, electrical and magnetic disturbances must be propagated with a finite velocity, and the theory of action at a distance must be doomed.

Before passing to the post-Maxwellian, or, as we may call it, the modern era, it may be convenient to state Maxwell's theory as he left it.

Electrical changes are related, not to the so-called field intensity, whose components are X, Y, Z, derivable from a potential ψ,

$$(1)\qquad X=-\frac{\partial\psi}{\partial x},\ Y=-\frac{\partial\psi}{\partial y},\ Z=-\frac{\partial\psi}{\partial z},$$

but to a new vector, called the electric displacement, and denoting the state of polarization discovered by Faraday. The components of this, f, g, h, are proportional to the components of the field,

$$(2)\qquad f=\partial\frac{K}{4\pi}X,\ g=\frac{K}{4\pi}Y,\ h=\frac{K}{4\pi}Z,$$

where K measures a physical property of the medium, Faraday's specific inductive capacity.

The density of the charge then is derived from the displacement by the equation

$$(3)\qquad \rho=\frac{\partial f}{\partial x}+\frac{\partial g}{\partial y}+\frac{\partial h}{\partial z}.$$

Similarly in magnetism we are to consider two vectors, the field α, β, γ, derivable from a potential Ω,

$$(4)\qquad \alpha=-\frac{\partial\Omega}{\partial x},\ \beta=-\frac{\partial\Omega}{\partial y},\ \gamma=-\frac{\partial\Omega}{\partial z},$$

and the induction, proportional to it,

$$(5)\qquad a=\mu\alpha,\quad b=\mu\beta,\quad c=\mu\gamma,$$

where μ measures another physical property of the medium. Maxwell here puts however

$$(6)\qquad \frac{\partial a}{\partial x}+\frac{\partial b}{\partial y}+\frac{\partial c}{\partial z}=0$$

so that the analogy with the electrical equation (3) is not quite perfect.

To the equations previously accepted giving the relations between the current density u, v, w, and the magnetic field produced by it,

$$(7)\qquad \begin{aligned}4\pi u&=\frac{\partial\gamma}{\partial y}-\frac{\partial\beta}{\partial z},\\ 4\pi v&=\frac{\partial\alpha}{\partial z}-\frac{\partial\gamma}{\partial x},\\ 4\pi w&=\frac{\partial\beta}{\partial x}-\frac{\partial\alpha}{\partial y},\end{aligned}$$

Maxwell adds the effect of the displacement currents, so that he has

$$(8)\qquad \begin{aligned}4\pi\left(\frac{\partial f}{\partial t}+u\right)&=\frac{\partial\gamma}{\partial y}-\frac{\partial\beta}{\partial z}\\ 4\pi\left(\frac{\partial g}{\partial t}+v\right)&=\frac{\partial\alpha}{\partial z}-\frac{\partial\gamma}{\partial x}\\ 4\pi\left(\frac{\partial h}{\partial t}+w\right)&=\frac{\partial\beta}{\partial x}-\frac{\partial\alpha}{\partial y}.\end{aligned}$$

The induced electromotive-forces due to changes in the magnetic field are represented by Maxwell in a somewhat peculiar manner, as the negative derivatives of a new vector called the vector-potential, so that

$$(9)\qquad P=-\frac{\partial F}{\partial t},\quad Q=-\frac{\partial G}{\partial t},\quad R=-\frac{\partial H}{\partial t},$$

The vector-potential is related to the magnetic induction by the equations

$$(10)\qquad \begin{aligned}a&=\frac{\partial H}{\partial y}-\frac{\partial G}{\partial z},\\ b&=\frac{\partial F}{\partial z}-\frac{\partial H}{\partial x},\\ c&=\frac{\partial G}{\partial x}-\frac{\partial F}{\partial y}.\end{aligned}$$

Thus the vector-potential itself does not appear, but only its time-derivatives.

The vector-potential was introduced by Maxwell to denote what Farraday termed the electro-tonic state of a body undergoing induction of current by magnetic changes.

Strangely, as it now seems, the ideas of

Maxwell were slow in gaining acceptation. We must not omit to notice that in 1867 an electro-magnetic theory of light was developed by Lorentz, but it was deduced from different considerations. It was not until the appearance of Maxwell's treatise, in 1873, that the attention of Continental thinkers seems to have been drawn to the new views. Already, however, had begun the appearance of that series of papers by the master hand of Helmholtz, which, beginning with a powerful exposition of the old electrodynamical theories, led by successive steps to the development of a theory similar to that of Maxwell, which, as the life of the great German drew to a close, became completely adopted by him. Otherwise, however, there is little to chronicle on the Continent until the appearance of the treatise of Mascart and Joubert, over a decade later than Maxwell's, showed that the seed had not fallen upon stony ground. Let us accordingly return to England, whither the center of gravity of the mathematical development of the subject was now transferred.

The first paper to appear in the *Philosophical Transactions* on Maxwell's theory was fifteen years later, by Fitzgerald, in 1880, on the 'Electro-magnetic Theory of the Reflection and Refraction of Light.' Here we find an extension of the suggestion made by Maxwell that the magnetic energy of the field contains terms depending on vortical motions about the lines of magnetic force, and thus an attempt is made to explain the phenomena of reflection of light from the surface of magnets, discovered by Kerr.

In 1881 followed a paper by Niven on 'The Induction of Currents in Infinite Plates and Spherical Shells,' the former being a subject which had been investigated by Maxwell. In 1883 the subject of electrical motions in spherical conductors was treated by Lamb, who, however, makes the simplifying hypothesis that the velocity of propagation of the inducing effect is infinite, that hypothesis not materially conflicting with any experiments then made. In 1884 appeared a paper by Larmor on the same subject.

In 1884 appeared a very important paper by Poynting on 'The Transfer of Energy in the Electro-magnetic Field,' where, by a direct application of Maxwell's theory, it was shown how the route taken by the energy in its passage from one plate to another during variations of the field could be described by the statement that the energy flowed everywhere perpendicularly to both the electric and magnetic field-vectors, at a rate proportional to the area of the parallelogram constructed on their geometric representatives. Thus, according to Poynting, the energy passes from a dynamo to a motor not through the wires connecting the two, but through the air, being guided in its course, however, by the wires. The ideas of Poynting were extended by Wien in two papers in *Wiedemann's Annalen* in 1892, as well as in a paper by J. J. Thomson, on 'Faraday Tubes of Force.'

In 1885 we have a still more important paper by J. J. Thomson, on 'The Application of Dynamics to Physical Phenomena,' in which, not especially the electrical ideas of Maxwell are developed, but rather the method introduced by him of applying Legrange's equations is extended to a great number of phenomena. Singularly enough the same sort of methods were soon to be used by Helmholtz quite independently for similar purposes.

In 1887 Lamb attacked the more difficult problem than that of the sphere of ellipsoidal current sheets, treating as a special case the flow of currents in a circular disc, and in 1888 the problem of induction of currents in shells of small thickness was treated by Burbury. The flow of current in cylindrical conductors has been treated by J. J. Thomson and Lord Rayleigh. In

all these researches upon current-flow, interesting questions regarding partial differential equations were treated, but much is still left for the mathematician to do. In fact, it was in this same year, 1888, that a striking sensation was produced in the scientific world by the publication of the experimental researches of a new genius, Heinrich Hertz, who produced in the laboratory the electrical waves conceived by Maxwell, and for the first time confirmed the theory by demonstrating the finite velocity of propagation. Experimental papers now succeeded each other with astonishing rapidity, confirming one point after another of the theory, and the experiments of Hertz immediately obtained a vogue which has not yet subsided. The energies of mathematicians were now taxed anew, for the question of the nature and period of the electrical motions in the curiously shaped 'oscillators' used by Hertz and his followers to produce the waves became very important. The previous investigations already described did not cover the case even for spheres and ellipsoids, for, in the case of vibrations of the rapidity now experimentally realized, the effect of the displacement currents could no longer be neglected nor could the velocity of propagation be considered infinite, while the phenomenon of radiation of energy from the conductor into space demanded mathematical recognition and treatment. This it failed to get, except in an approximate manner, for anything except the simplest case, that of the sphere. This was treated by J. J. Thomson and Poincaré. Nevertheless, the theory has not been experimentally verified for the sphere, because the sphere is a badly-shaped conductor for experimental purposes. In order to retain energy enough to maintain the vibrations for a number of oscillations, the conductor should be long or even dumb-bell-shaped, and not at all like a sphere.

The long spheroid is then next to be attacked, and then other surfaces, perhaps those obtained by the revolution of the curves known as cyclides. The introduction of suitable curvilinear coordinates into the partial differential equation concerned,

$$\frac{\partial^2\phi}{\partial t^2}=a^2\Delta\,\phi$$

will lead, even in the case of the spheroid, to new linear differential equations analogous to but more complicated than Lamé's, and will necessitate the investigation of new functions and developments in series.

The remarkable experimental skill shown by Hertz is not his only title to our admiration. His inaugural dissertation had been a treatment of the flow of electricity in spheres, and his electrical researches received a fitting completion in two mathematical articles in which Maxwell's theory was systematized and stated in an extremely clear and symmetrical manner. The equations of Maxwell, stated above, are unfortunately lacking in symmetry, and certain questions that have since arisen were not contemplated by him. These improvements were made in a very satisfactory manner by Hertz, as we shall describe later. We can not, however, award to Hertz the credit of priority in this matter, for the work had already been done by another writer, of whom I must now speak at length—I mean that extraordinary Englishman, Mr. Oliver Heaviside. Of this undoubted genius I feel that it is no exaggeration to say that he understands the theory of electricity probably better than anyone else now living. Of a decidedly eccentric personality and mode of expression, unknown to and unseen by most of his scientific countrymen, this self-taught luminary appeared on the horizon over twenty years ago, and slowly but surely approached the brilliancy of a star of the first magnitude. Unnoticed at first, he forced himself upon the attention of physicists by the sheer quantity of his pro-

ductions, and it was then found that their quality was also exceptional. His writings have mainly dealt with a quite different sort of subject from those enumerated above, and have treated either the flow of variable currents in wires or the transmission of electro-magnetic waves in free space. As early as 1876, in a paper modestly entitled 'On the Extra-current,' he gives for the first time the partial differential equations for the propagation of current and potential along wires, and treats them by the methods of Fourier. Later he considers the most complicated questions caused by the terminal conditions involved by the introduction of various sorts of electrical apparatus, such as those used in telegraphy and telephony. These papers will well repay the attention of pure mathematicians, to whom they offer a host of questions for rigid treatment. For instance, to fix the ideas, we have the equation of propagation

$$a\frac{\partial^2\phi}{\partial t^2}+b\frac{\partial\phi}{\partial t}=c\frac{\partial^2\phi}{\partial x^2}$$

with the condition that for two or more given values of x, φ is to satisfy given linear *ordinary* differential equations in t, and that for a given value of t, φ and $\frac{\partial\varphi}{\partial t}$ are to be given functions of x.

If we attempt to satisfy the equation by particular solutions which are trigonometric functions of the time we get an ordinary differential equation in x, and if we then make use of trigonometric functions of multiples of x the multiples allowable will be determined by certain transcendental equations according to the terminal conditions. The function φ is then to be developed in a series of such trigonometric terms. The nature of the proofs desired relating to the series may be readily inferred. The papers by Heaviside are extremely numerous and bulky, and it is desirable that the methods there used should receive critical attention from mathematicians, for it must be said that Heaviside uniformly disdains such things as existence-theorems, depending chiefly on his intuitions drawn from physical reasoning.

A large portion of Heaviside's labors has been devoted to the systematization and extension of Maxwell's theory and the attempt to disseminate a knowledge of that theory among the physical public. His results agree so nearly with those of Hertz that I shall give them in the notation and form used by the latter, which seem to me preferable. The attempt to bring out the symmetry or reciprocity between electrical and magnetic phenomena has been paramount with both Heaviside and Hertz. Accordingly, we have for the connections between the electric and magnetic field intensities, represented respectively by X, Y, Z and L, M, N, and the corresponding inductions or polarizations $\mathfrak{X}$, $\mathfrak{Y}$, $\mathfrak{Z}$ and $\mathfrak{L}$, $\mathfrak{M}$, $\mathfrak{N}$,

$$(11)\qquad \mathfrak{X}=\varepsilon X,\quad \mathfrak{Y}=\varepsilon Y,\quad \mathfrak{Z}=\varepsilon Z \qquad\Bigg|\qquad \mathfrak{L}=\mu L,\quad \mathfrak{M}=\mu M,\quad \mathfrak{N}=\mu N \qquad (12)$$

instead of equations (2) and (5), ε representing the specific inductive capacity and μ the magnetic permeability. For the electrical and magnetic densities ρ_e and ρ_m we have

$$(13)\qquad \rho_e=\frac{1}{4\pi}\left\{\frac{\partial\mathfrak{X}}{\partial x}+\frac{\partial\mathfrak{Y}}{\partial y}+\frac{\partial\mathfrak{Z}}{\partial z}\right\},$$

$$(14)\qquad \rho_m=\frac{1}{4\pi}\left\{\frac{\partial\mathfrak{L}}{\partial x}+\frac{\partial\mathfrak{M}}{\partial y}+\frac{\partial\mathfrak{N}}{\partial z}\right\}.$$

For the mutual connections of the two fields we have

$$(15)\qquad \begin{aligned} 4\pi u+\frac{\partial\mathfrak{X}}{\partial t}&=\frac{\partial N}{\partial y}-\frac{\partial M}{\partial z},\\ 4\pi v+\frac{\partial\mathfrak{Y}}{\partial t}&=\frac{\partial L}{\partial z}-\frac{\partial N}{\partial x},\\ 4\pi w+\frac{\partial\mathfrak{Z}}{\partial t}&=\frac{\partial M}{\partial x}-\frac{\partial L}{\partial y},\\ -\frac{\partial\mathfrak{L}}{\partial t}&=\frac{\partial Z}{\partial y}-\frac{\partial Y}{\partial z},\end{aligned}$$

$$(16) \qquad -\frac{\partial \mathfrak{M}}{\partial t}=\frac{\partial X}{\partial z}-\frac{\partial Z}{\partial x},$$
$$-\frac{\partial \mathfrak{N}}{\partial t}=\frac{\partial Y}{\partial x}-\frac{\partial X}{\partial y}.$$

Thus, with the exception of the electrical currents u, v, w on the left of equation (15) and the negative sign in (16), we have complete analogy between the electrical and magnetic equations. In these equations neither the electric nor magnetic potentials nor the vector potentials appear, and we are concerned only with the two field intensities, which have a more tangible existence than the potentials. While equations (15) are identical with (8), equations (16) take the place of (9) and (10), for if we differentiate equations (10) according to the time, and substitute on the right for the time-derivatives of F, G, H, their values from (9), we obtain (16).

In order to obtain the result of propagation with finite velocity, let us consider a non-conductor, where u, v, w are zero, and let us suppose ε, μ to be constants. Differentiating the third of equations (16) according to y and subtracting from the second differentiated according to z gives

$$\frac{\partial}{\partial t}\left\{\frac{\partial \mathfrak{N}}{\partial y}-\frac{\partial \mathfrak{M}}{\partial z}\right\}=\frac{\partial^2 X}{\partial x^2}+\frac{\partial^2 X}{\partial y^2}+\frac{\partial^2 X}{\partial z^2}$$
$$-\frac{\partial}{\partial x}\left\{\frac{\partial X}{\partial x}+\frac{\partial Y}{\partial y}+\frac{\partial Z}{\partial z}\right\}.$$

Substituting the value of the parenthesis in the left from the first of equation (15), after making use of equations (11) and (12) and assuming that the parenthesis on the right vanishes, since there is no free electricity, gives

$$\varepsilon\mu\frac{\partial^2 X}{\partial t^2}=\frac{\partial^2 X}{\partial x^2}+\frac{\partial^2 \gamma}{\partial y^2}+\frac{\partial^2 Z}{\partial z^2},$$

which is the equation for the propagation of waves, as we have it in the theories of sound and light. The velocity of propagation is $\frac{1}{\sqrt{\varepsilon\mu}}$.

The last paper of the series of Hertz treats of the equations to be used in connection with moving bodies, and besides introducing terms accounting for the remarkable discovery by Rowland of the magnetic effect of a moving charge of electricity suggests several matters not yet verified by experiment. Still deeper into the theory goes an elaborate paper by Heaviside on the 'Forces, Stresses and Fluxes of Energy in the Electro-magnetic Field,' published in the *Philosophical Transactions* of 1892. In this paper Heaviside deals with matters which are still open to controversy.

The last contributions of Helmholtz to the theory were his paper on the 'Principle of Least Action in Electrodynamics,' published in 1893, in which he seeks to deduce all the electrical equations from this fundamental mechanical principle, and his paper on the 'Electro-magnetic Theory of Dispersion,' in which he adapts his beautiful explanation of this complicated optical phenomenon to the electro-magnetic theory.

I have time here only to mention researches on electro- and magneto-striction, or change of form and shape of bodies in electric or magnetic fields, to which contributions have been made by Helmholtz, Boltzmann, Kirchhoff, Stefan, Lorberg, Adler, Cantone and Duhem, and on the magnetic effects produced by the motion of electrical charges, upon which subject papers have appeared by J. J. Thomson, Heaviside and Searle.

Before closing I must, however, mention several elaborate papers by Larmor, begun in the *Philosophical Transactions* for 1894, in which the attempt is made to propound a dynamical theory of the ether, which shall not only give a suitable explanation of light, but also a dynamical theory of all electric and magnetic phenomena, including the electro-magnetic theory of light. For this purpose the old theory of McCullagh is found to be available and is developed with extremely interesting results, while a great variety of phenomena are dealt with.

I have here made no mention of the work that has been done on the various theories of the mutual actions at a distance of current elements, as these are thoroughly dealt with in J. J. Thomson's admirable British Association report on electrical theories in 1885. I have thus, in a very brief and unsatisfactory manner, merely touched upon some of the principal points of the development of the theory of electricity, and traced its gradual but unceasing progress from the hands of the giants of the old days to those of the new.

ARTHUR GORDON WEBSTER.
CLARK UNIVERSITY.

THE LIMITATIONS OF THE PRESENT SOLUTION OF THE TIDAL PROBLEM.

THAT which is new in science is always interesting. But it is well at times to let the old and well-tried pass in review before us, to plan renewed attacks upon the unknown, in the light of the elements of strength or weakness found in different portions of the army of known facts and principles, and with respect to the stubborness of the resistance which has been encountered by attacks upon different parts of the unknown. A helter-skelter attack may perhaps produce more interesting and more surprising results than a well planned campaign, but the latter would be expected to furnish the more important results. The purpose of this paper is not to state anything new, but to point out a very weak point in tidal theory, a point which it is important to have strengthened, and of which the strengthening is apt to lead to a decided advance in our knowledge of the subject.

The thesis which I submit is that the present theory of the tides upon the earth when used to explain those tides, or to predict their occurrence at a particular point, furnishes very little except the *periods* of the separate harmonic, or invariable, components of the tide. It does not furnish the times of occurrence of the tides, that is, the epochs of the components, nor does it furnish the range of the tide as defined by the amplitudes of the harmonic components.

This thesis may be exhibited in concise form by writing the algebraic expression for the height of the tide referred to mean sea level at any instant at a given point

$h = A_1 \cos (\alpha_1 t + \beta_1) + A_2 \cos (\alpha_2 t + \beta_2)$......

Each term of this expression indicates one of the harmonic components of the tide. From pure theory, reasoning from the known motions of the Moon, Sun and Earth and the Newtonian law of gravitation, it has been shown that if certain definite values be assigned to the quantities $\alpha_1, \alpha_2, \ldots$ (fixing the periods of the separate terms), that each term truly represents one of the invariable components of the tide. Here, after *merely* fixing the periods of the separate components the contribution of tidal theory ends, and the work of direct observation at the particular station under consideration begins. The values of A_1, A_2, defining the amplitudes of the separate components and the range of the composite tide, and of β_1 $\beta_2 \ldots$ fixing the epochs of the separate components and the time of the tide, must be derived directly from observations at the particular station in hand. Their values cannot, at present, be assigned even approximately from theory.

If we look at the *actual* tidal problem presented to us by Nature the reason why theory furnishes so little will become evident. In approaching the actual problem let us begin by considering a simple ideal problem which can be and has been successfully handled, and then introduce into this problem, one by one, the *actual* conditions which modify it. In doing so we may, to a certain extent, follow the historic order of tidal research.

There are tides produced by both the Moon and the Sun. To avoid circumlocu-

tions we will deal explicitly with the lunar tides only.

We may start with the problem of determining the shape of the free ocean surface on the supposition that the Earth consists of a rigid nucleus completely covered with a great and uniform depth of water and upon the supposition that the Moon moves in a circular orbit in the plane of the Earth's equator at such a rate that one face of the Earth is always presented to the Moon, just as the Moon now always presents the same face to us. Roughly speaking, the ocean in this case would become an ellipsoid with its major axis in the line joining the centers of the Earth and Moon, and this tide, if we may call it so, is the so-called static or equilibrium tide. This problem has been completely solved.

As a next step toward the actual problem, let the Moon be supposed to remain in a circular orbit in the plane of the Earth's equator, but let its period in that orbit be twenty-seven days, as at present it is. The Earth now presents different parts to the Moon in rapid succession as the Earth rotates once on its axis in each solar day. At once the problem becomes much more difficult than before ; for the effects of viscosity of the water, of its inertia and of friction against the ocean bottom combine to reduce the height of the wave, to modify the shape of the wave, to cause its crest to lag behind the Moon. The problem is now that of dealing with a *forced* wave—a much more difficult one than the static problem just outlined, and more difficult than that of dealing with a free wave. But it is still a problem which has been so thoroughly investigated that there is comparatively little hope for a new worker to extend our knowledge much along this line.

The introduction of the actual Moon with its rapid changes in declination and distance, and its variable motion in right ascension, in the place of the fictitious Moon we have been considering, makes the problem heavier, but not essentially much more difficult.

From the theory of wave motions in liquids it has been shown that for a wave, such as the tidal wave, of which the length from crest to crest is great in comparison with the depth of the water, the rate of progress of the wave is connected with the depth by the law $V = \sqrt{gh}$, in which V is the velocity of progress of the wave, g the acceleration due to gravity and h the depth of the water. According to this law a free tidal wave would succeed in keeping pace with the Moon in its apparent progress around the Earth only in case the assumed uniform depth of the water is greater than thirteen miles. If the uniform depth be assumed less than thirteen miles the old wave will, in effect, be continually being lost in the race and a new wave be continually being built up in front of it. The tide of our previous problem will be still further reduced in range and modified in shape and will lag still further behind the Moon, which produces it. The problem is still tractable, though exceedingly difficult, and still falls in the category of thoroughly investigated problems.

Now let the problem become nearer like that of Nature by supposing the shape of the surface of the solid portion of the Earth to be just what it is in fact, an irregular succession of great continental elevated areas, great oceanic basins, mountain ranges, broad valleys, great plateaus, etc. Let the problem still differ from that of Nature by supposing that the water level is just high enough to cover the summit of Mt. Everest, so that the whole Earth is covered with depths varying from zero, at Mt. Everest, to ten miles, on a few small areas at the deepest portions of the oceans. If, under these conditions, an attempt is made to follow the history of the wave in its westward progress, the problem will at

once be found to be exceedingly difficult, if not intractable, though the problem is still much simpler than that presented to us by Nature.

The depths being everywhere less than thirteen miles, the wave will at no point be able to keep pace with the Moon. The apparent rate of progress of the Moon over the Earth's surface is about seventeen miles per minute. The rate of progress of the wave will be about fifteen miles per minute where the depth is ten miles, and less than five miles per minute where the depth is not greater than one mile.

Let an attempt be made to trace a tidal wave westward, starting from the 180th meridian in the Pacific. The northern portion of the wave will be confronted by the full width of both Asia and Europe; the middle portion will have deep water across the Indian Ocean, but will be obliged to cross submerged Africa before reaching the Atlantic; while the southern portion will have unobstructed deep water to and beyond the Cape of Good Hope. This southern portion, rounding the Cape of Good Hope, will necessarily be propagated northward up the Atlantic, as well as westward, for the middle portion, travelling in shallower water, will not yet have reached the Atlantic. The middle and northern portions of the wave will have acquired an irregular front on account of the various depths traversed by different portions. This Cape wave, as it progressed northward up the Atlantic valley, would combine at an angle in some complex fashion with the irregular wave emerging gradually from the shoals of Africa, and finally from Europe. In short, even with the conditions so far imposed, it would be exceedingly difficult, if not impossible, with our present knowledge, to compute the wave to be found in the Atlantic, to say nothing of the additional complexity produced when this already complicated wave crossed the submerged Americas.

Still we are dealing with a problem very much simpler than that of Nature. In the actual case the Moon would outstrip the wave in its westward progress, and then the direct effect of its attraction would be to tend to tear down the old wave and build up a new one in advance of it. This action would bring about radical modifications in the wave, even within one trip around the globe.

Moreover, the variations in depth produce other effects upon the wave fully as important as the one just considered. The increased friction in small depths tends to reduce the height of the wave. On the other hand, when a wave passes from deep to shallow water there is a tendency for the wave to attain a much greater height than before, since nearly the same amount of kinetic energy must be concentrated in a much smaller amount of water. So a tidal wave continually varies between wide limits in amplitude, as well as in its rate of propagation, in a way that is exceedingly difficult, to say the least, to compute. These variations in range produce obvious difficulties in such a case as that just suggested, in which waves from different regions coalesce.

As one more step in making our assumed problem approach the actual problem, let the water surface, which has been supposed to be at the level of the summit of Mt. Everest, subside to its present actual position. One-fourth of the earth's surface becomes dry land. There is now in the problem all the previous intricacies, and in addition a new set of difficulties, arising from the fact that the oceans are bounded by irregular shores, from which the tidal wave is *reflected* to a greater or less extent at every point of contact. The *actual* tidal waves may as properly be compared to a choppy sea, such as may be seen along the docks of a crowded port, as to a regularly progressive wave passing to westward around the

earth, as pictured in the minds of most people.

Tracing the actual tidal wave as best we can by direct observation, we find that by starting at a point off the west coast of South Africa the wave is separated into two waves, one of which goes westward and the other eastward. If we follow that portion of the wave which has the least obstructed path, passing across the open Pacific to the southward of Australia and to the Cape of Good Hope, we find that after *thirty-six* hours it has not yet circumnavigated the globe, but instead has just reached the neighborhood of Cape Horn and is there apparently lost in a collision with an *eastward-bound* tidal wave, which started in the Pacific, off the west coast of South America, twenty-four hours later than the wave which we have followed. Looking to other portions of the oceans we find that the tidal wave moves northward rather than westward over the whole Atlantic and a part of the Pacific—in fact, on about one-third of the total ocean surface; and that the progress has a decided *eastward* tendency in at least two large areas, in the Arctic ocean north of Europe, and in the Pacific off the west coast of South America.

If we examine the relative amplitudes of the harmonic components of the tide at different stations we shall find further strong evidence of the radical modifications made in the astronomical tide by the influence of shores and bottom. As a typical case we may note that in the Atlantic the semi-diurnal components are large as compared with the diurnal components, so that there are always two tides of nearly the same height per day, whereas in the Pacific the amplitude of the diurnal components approaches that of the semi-diurnal components and in some cases exceeds it, and as a result the two Pacific tides of the same day are in general of decidedly different heights and in certain extreme cases but *one* tide occurs per day. In one of the extreme cases, at Batavia, Java, the component which has *one* high water per *sidereal* day is more than six times as large as the component having two high waters per lunar day, although in the astronomical tide the latter predominates over all others.

Out of the conflict with the shores and bottom the astronomical tide preserves only its periods, and hence in making tidal predictions at a given station theory can furnish us nothing but said periods. In the conflict no period is lost, though the amplitudes corresponding to certain periods may be greatly decreased or increased, and no new periods are known to be produced save certain multiple periods, or overtones, so to speak, produced by friction, and an annual period fixed probably in the main by meteorological causes.

When the prediction is made it applies to *one point* only, the point at which the observations were made, and with our present lack of ability to predict the effect of boundaries upon the range, the shape, and the rate of progress of the tidal wave that prediction can be extended even by careful study of charts but a very few miles from the stations of observation before acquiring large errors.

The effects of the boundaries—bottom and sides—can best be studied in bays and rivers, in bodies of water in which observations are available at many points, and in which the direct effect of the Moon and Sun is small as compared with that of the wave transmitted from the ocean. The tide tables and charts issued by the Coast and Geodetic Survey furnish many fine opportunities to study this problem. For example, the charts issued by that Survey give complete and detailed information as to soundings in the Chesapeake Bay and its tidal tributaries, and the tide tables give complete harmonic data for Old Point Comfort, Baltimore and Washington, and data

as to time and mean range of tide for forty-nine other points on Chesapeake Bay, and for twenty-eight points along the Potomac River, to say nothing of sixty-one points on other tributaries of the bay. For such a region the investigator has an ample collection of facts to be used in proving or disproving any theory which he may formulate.

I am inclined to think that whoever successfully attacks this problem will use a graphic, or partially graphic method, plotting his results step by step upon the chart. In any wholly analytic method it will be especially difficult to take sufficiently into account the configuration of the bottom and shore.

In conclusion, I submit that to solve this boundary problem is to make an immense stride in our knowledge of the tides, a stride corresponding to a half century of ordinary progress; that it is in this line that our ignorance of the tides is most dense; that the facts are at hand for the investigation, and that, judging from the literature of the tides, this is, *comparatively speaking*, an unworked portion of the field. Along this line considerable pioneer work has been done, especially along purely mathematical lines, but the new comer will find neither a long series of failures to discourage him by indicating that the problem is intractable, nor a long series of successes to discourage him by making it appear that there is little opportunity to advance beyond what has already been done by others.

* * * * * *

It may seem that in this paper some attention should be paid to the fact that theory furnishes the relative amplitudes of certain harmonic components; that, in particular, theory indicates that certain relations exist between the relative amplitudes and the mass of the Moon, and that this theory has been born out by the fact that said mass has been computed with a high degree of accuracy from tidal observations.

It should, however, be kept clearly in mind that only the *relative* amplitudes are concerned in the computation of the Moon's mass. Further, the mass of the Moon as deducted from observations at a single tidal station is often largely in error. An accurate determination of the mass is obtained only when the results of observations at many stations are combined.

There is a decided significance, in the present connection, in the conclusions reached by two investigators who have carefully studied this phase of the tidal problem. Professor Ferrel, after a prolonged consideration of the matter, concludes that, to secure a better determination of the Moon's mass from the tides, a special study of 'shallow water components' should be made. In other words, the effects of friction due to the boundaries must be studied. Professor Harkness, in deriving the Moon's mass from tidal observations,* gives all stations equal weight, though the length of the series of observations varies at the different stations from one to nineteen years, on the ground that 'the accidental errors at any station are generally small as compared with those due to constant causes.' He indicates in the context that these 'constant courses' are constant for each point, but variable in passing from point to point along a coast; in other words, they are due to the local peculiarities of the boundaries.

John F. Hayford.

GEOMETRICAL OPTICAL ILLUSIONS.

During the last few years the subject of Optical Illusions has been receiving a degree of attention that may well be called remarkable. Both popular and scientific articles have been written, so that the general public, as well as the specialist, is well

* On the Solar Parallax and its Related Constants, Wm. Harkness, pp. 119–120.

informed about the simplest forms of the most interesting types of illusion. The signal for the scientific discussion of the subject seems to have been given in 1889 when Müller-Lyer first published the 'figures' which now bear his name. The investigations and discussions that grouped themselves about these particular figures soon spread to the whole field of optical illusions, until there grew up that body of technical literature which to-day has assumed very respectable dimensions. It is not so much that new forms of illusions have been devised or discovered—although more than one valuable contribution has been made—as that the heretofore well-known illusions have been subjected to a closer scrutiny than ever before. Like everything else accessible to experimentation, illusions have been taken into the laboratory. Variants, possessing characteristics that differ somewhat from the original form, have been devised. Each figure has been dissected and analyzed that it might be reduced to the lowest terms. And, above all, each figure has been subjected to a quantitative investigation, the amount of the illusion being accurately measured under the widest possible variety of conditions. These results in turn have been made the basis of theoretical considerations, and the end sought has, of course, always been some satisfactory *explanation* which shall furnish adequate grounds for the presence of an illusion in any given case. It is here that the war has waged. For while, in general, there has been sufficiently close agreement in reference to the results of experimental observation, there has been small uniformity in the theoretical conclusions reached. The one great attempt of to-day is, therefore, to bring harmony into this field; to establish, if possible, some single point of view which shall be applicable to all geometrical optical illusions alike, and which shall furnish that wished-for, comprehensive unity among the seemingly scattered and unrelated facts. That this attempt has met with complete success can hardly be asserted. Theories fundamentally antagonistic stand side by side with others that seek to combine and reconcile, and the day of perfect agreement seems yet distant enough. The splendid attempt of Wundt* to connect all illusions with actual or attempted *movements of the eyes;* the no less earnest attempt of Thiéry† and Filehne‡ to establish an explanation in terms of *perspective*; the classic attempt of Helmholtz and, more recently, of Heymans§ and Loeb to apply in one form or another the principle of *contrast*, and the very pretensious effort of Lipps¶ to define and utilize an *æsthetic* principle of unrestrained and victoriously striving activities, or their opposites, are all cases in point.

Perhaps the clearest way to give those readers of SCIENCE who, while interested in the subject, are unable to follow the technical literature closely and at first hand, some impression of the more recent work that has been done, will be to consider, in the first place, the discussions that have centered about some of the best known illusions, leaving until the end the account of the various explanatory principles that have been advanced and vigorously defended.

A.

1. *Zöllner's Pattern.*—In one or another of its many forms every one is familiar with the illusion of Fig. 1, in which a set of parallels is made to appear alternately convergent and divergent, by the addition to them of transverse cutting lines. But

* Wundt. Die geometrisch-optischen Täuschungen, 1898.

† Thiéry. Philosophische Studien., XI and XII.

‡ Filehne. Zeitsch. f. Psych., etc., XVII (1898): 15.

§ Heymans. Ditto., XIV., 118.

¶ Lipps. Raumæsthetik u. geometrisch-optischen Täuschungen, 1897.

familiar as this figure is, discussions in regard to the principles that should be applied to its explanation are by no means at an end. Two theories, especially, are at present contending for the primacy: the one, namely, falling back upon the supposedly

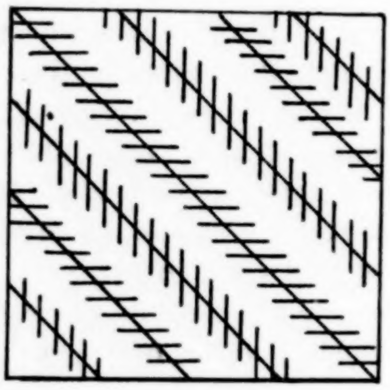

FIG. 1.

fundamental principle that when acute and obtuse angles come together in the field of view the former are relatively overestimated, the latter underestimated; the other appealing to perspective principles and calling attention to the fact that the above figure is to be seen, not as lying wholly in the plane of the paper, but as presenting elevations and depressions, projecting ends of lines and well-defined ridges. The first theory is well enough understood to render extended comment unnecessary. Suffice it to say that the main lines, rather than the short transversals, are affected by this false estimation of angles for the very obvious reason that they form in each case the common side of a multitude of angles. For a long time this theory was content to stand in this simple form. But the plastic phenomena of the figure, which we shall have to consider in a moment, are to-day too evident to be lightly disregarded. Hence the most recent statement of this theory* takes full account of the prospective phenomena present, but relegates them to a secondary position, making them dependent upon the already present deflections of the main lines.

In sharp contrast to this are the claims of the second theory. For it perspective influences are primary and all-sufficient. The observations, made long ago by Hering and Guye, to the effect that a careful attention to the figure will reveal unmistakable plastic characteristics, are here again emphasized. Especially if the above figure be drawn upon glass and viewed against a uniform background, the tri-dimensional properties become clearly apparent.* Not only do the ends of the main lines run alternately above and below the plane of the drawing, but, further, the transversals seem so to slope that if prolonged they would meet in ridges similarly above and below the plane. Accordingly, the illusion is due to the *interpretation* that we give the figure. We see the actual parallels projected, as it were, upon the surfaces of solid and hollow prisms which lean away from the vertical, and the lines being actually parallel the observer must interpret the more remote ends as diverging, as would actually be the case in ordinary perspective vision. In other and more general terms, the preponderatingly tri-dimensional character of all our visual experience compels us to interpret in the light of this every perspective motive that any linear drawing may contain. In the figure before us the arrangement of lines recalls by association certain real experiences with similar elements, and forthwith all the attributes that would be given to the lines and parts of a real seen object are given to the linear drawing, even though the observer be not consciously aware of anything beyond the final perception which turns out to be illusory.

Such in mere outline are the two opposing theories which to-day seem likely to

* Wundt., Op. cit.

* The observer should always remember that the perspective elements of any figure are most clearly seen when *one* eye only is used.

arouse discussion most seriously. To be sure, there are other theories in the field, but they may perhaps remain unmentioned here. How these two theories fare when they descend to details we must consider later.

Attention has been called recently in a very interesting way to certain phenomena of movement that are to be observed upon the heavy original Zöllner pattern shown in Fig. 2.* In his *Physiologische Optik*

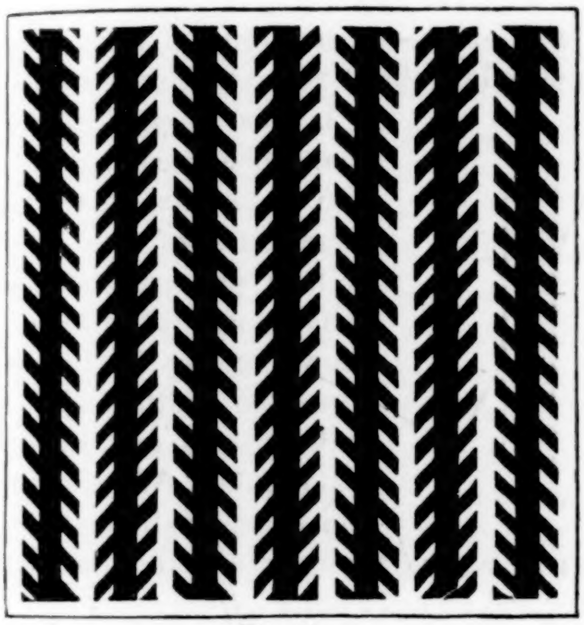

FIG. 2.

Helmholtz called attention to certain facts that appear to be less universally known than their importance would seem to justify. He noticed that if any small object, as the head of a pin, be steadily fixated while drawn horizontally across this diagram the heavy verticals appear to be set into motion in the direction of their own lengths, adjacent lines moving in opposite directions. The necessary rate of movement for the fixated point can be determined readily for each observer. If this motion be from left to right those lines bearing upward running transversals will seem to shoot upwards, those bearing downward running transversals downwards, and if the carefully fixated point be moved back and forth over the diagram a most startling unsteadiness is produced in it. Now the movements recently noticed by Filehne are very similar to these in appearance. They are to be seen thus: Placing the diagram so that the main lines lie horizontally, view it, not too fixedly, through a tube blackened within. Movements of diagram and tube being obviated in some way, a few moments' careful gazing will reveal the fact that the horizontals, two, three or more at a time, are darting about to the right and left, during a period of from one to three seconds. The motion of any particular horizontal is seen to be always *in the direction of the overhanging ends of the obliques.* Though it is affirmed that these phenomena may be seen even when the possibility of eye-movements is excluded, the writer finds slight movements absolutely essential, such, for example, as are produced by beginning to close the eye. Though most easily seen, perhaps, when the lines of the diagram are placed horizontally, these movements are none the less to be seen in the vertical position. Those lines that before darted to the left now pass upwards. If placed in an oblique position a peculiar fact may be noted. If the lines run upwards from right to left the observed motion will be upwards for those lines that before moved to the left and upwards respectively. But if the lines run upwards from left to right no motion is to be seen, since, while the tendencies to motion found in the horizontal and vertical positions have reinforced each other in the first oblique position, they are such as to cancel each other here. But in any case, whenever motion occurs, it takes place in the direction of the overhanging ends of the obliques The reason for these phenomena Filehne claims to find in the consideration of 'memory-images of motion.' His theory is supplementary to the general perspective theory of which he is an earnest advocate. Many of our visual

* Filehne, Loc. Cit.

experiences are had while we are in motion. In such cases the angle made by any upright object that is perpendicular to the earth changes as we approach it or recede from it. This change is always of such a kind that, as we approach, the angle appears to diminish from an obtuse to a right angle, and as we reach and pass beyond the object the angle seems to increase, the perpendicular appearing, that is, to fall gradually away from the moving observer. But whether the observer be approaching or receding, the apparent movement—which may be regarded as a rotation about the point of contact with the ground—is always opposite to the direction of the observer's progress, and always towards that position where it shall seem to tip away from the observer as he has passed by. Most strikingly, possibly, is this seen in railway travel. The telegraph poles seem to rotate as they fly past, and always in the direction of that position where they shall appear to overhang. Well, countless experiences of this kind have stored up such a mass of memory-images that when, as in the Zöllner diagram, similarly overhanging obliques are viewed, these latent images are brought to the threshold of consciousness and the diagram itself becomes enlivened with an illusory motion, occurring in strict accord with actual objective experience. Psychologically considered, the language used is not wholly free from objection, but the meaning of the theory is on the whole clear enough. It has seemed well to report these new observations at some length, since their importance for the theory of optical illusions is evident. Filehne asserts the complete lack of connection between the illusory movements described by himself and those mentioned by Helmholtz. To the writer, however, it would seem that the two sets of phenomena are very closely related. Whether this be so, only a careful and more extended examination of the matter can determine. The alleged movements, or their lack, are too difficult of observation and too elusive of rigid verification to admit of any positive statements at present. Nevertheless the question may be asked very pertinently, how any visual impression, of whatever characteristics, should be capable of causing illusory perceptions of movement at a moment when every actual movement of the eyes is excluded. Certainly, if the observations recorded be true, we have something novel in the realm of psychology—a perception of motion, but a motionless object and a motionless eye.

FIG. 3.

2. *The Poggendorff Illusion.*—The secondary illusion to be seen on the oblique lines of the heavy Zöllner pattern, the more usual form of which is shown in Fig. 3, still continues to be the object of experimental and theoretical inquiry. We meet here the same contrasted theories as before, though we find them somewhat less sharply stated.

The explanation that rests upon the overestimation of acute angles has, as usual, little difficulty with the matter. The free ends of the transversal are simply rotated about the points of contact with the verticals, with the result that a new line may be drawn at either end in apparent continuation of the other. It would seem also, as Wundt has pointed out, that other factors cooperate to produce the illusion, since its amount is much diminished by giving the figure a horizontal position. One such factor is doubtless the universal tendency to overestimate the upper as opposed to the lower half of any vertical dimension. Another factor may well be the likewise universal tendency to underestimate empty as opposed to filled spaces. Underestimating the open space between the inner ends of

the transversal would result in an apparent narrowing of the vertical strip and a consequent increase of the illusion. But this latter factor is probably effective here in a minimum degree.

Somewhat more interesting is the perspective explanation. This we meet under two different forms. The first employs the usual perspective argument. Carefully viewed, the ends of the transversal may be seen to issue from the plane. This becomes especially evident if the figure be made of wire and suspended before a uniform background. In consequence of this perspective quality of the figure the visual angle made by the transversal and the vertical is interpreted as *representing* an angle of greater magnitude than that seen, just as in the case of all angles seen perspectively in objective vision, and the illusion results. This, if I rightly understand him, is the argument of Thiéry. The second form of the perspective explanation differs quite materially from this. It is the explanation of Filehne. According to this the vertical strip of the Poggendorff figure serves principally to sunder the two ends of the transversal to such a degree that there is no longer any sufficient reason for regarding them as belonging together. Now, remembering that, in accordance with the perspective theory in general, the lines of a plane geometrical figure act chiefly as the means of suggesting real objects of actual experience, we can easily see the line of thought. For there is not the remotest necessity that two detached portions of a straight line represent objects whose bounding edges should appear continuous, merely because they would meet and form a continuous line in the linear drawing that represents them. It can be most readily and graphically shown by straight-line drawings of objects that two detached portions of one and the same line may represent objects in totally different planes of space, so that if the objects represented were to be prolonged in their own direction they might never meet at all, or at best only at an oblique angle. In the figure before us, consequently, it is highly probable that the sundered portions of the oblique recall some real experience, or set of experiences, in which the objects represented are absolutely unconnected. Such an experience may be suggested by a finger-post, an arm upon one side pointing obliquely towards the observer, an arm upon the other side—lower or higher, as the case may be—pointing obliquely away. Herr Filehne finds great support for this view in the alleged observation that every trace of the illusion vanishes in the above figure if only the two verticals be somehow united, or if some indications be present to show that the ends of the transversal are portions of a continuous whole, the missing part of which is hidden behind the vertical strip. The first condition can be secured by drawing within the latter a short line which shall be oblique to the transversal and meet the edges of the strip at points opposite those in which the ends of the transversal terminate. The second condition can be readily secured by making the transversal represent a pointed stick, or by placing at the outer ends of the transversal the drawing of some such device as weights and pulleys, which shall make it clear that the two ends are really acting in unity. But though these conditions be fulfilled to perfection, the illusion simply does *not* vanish, despite the assertion of Filehne to the contrary, nor would one expect it to do so. For what these particular devices are expected to accomplish is the closer approach to the actual conditions of tri-dimensional vision, where only one interpretation of the lines is possible. The best conditions for testing the theory would be found, therefore, in normal objective experience. Stretch a rope obliquely behind a tree trunk and at a distance of

some feet from it. The illusion persists, and yet there is no possible attempt to give an independent perspective interpretation to either end of the rope. Still more conclusive, perhaps, is the consideration of the so-called 'Illusion of the Gothic Arch,' a representation of which is given in Fig. 4.

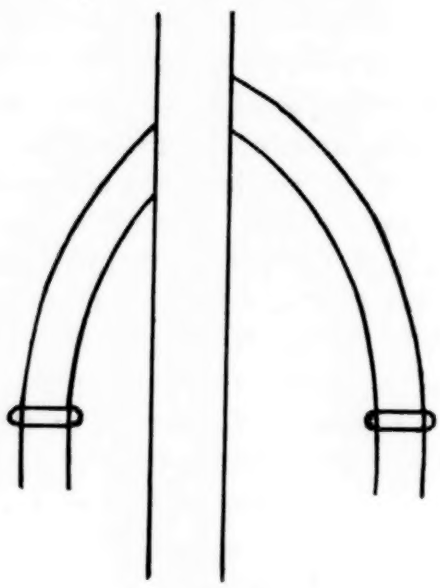

Fig. 4.

This illusion, many times independently observed, is manifestly but a variant of the more simple rectangular form, and its striking quality is not destroyed even though the observer be most intensely conscious that he is in the presence of actual objects, seen under the conditions of normal perspective. It seems most necessary, therefore, to look askance at this most recent attempt to apply the perspective interpretation to the Poggendorff figure.

One point seems to have been universally overlooked in the quantitative investigations made upon this figure. All measurements, namely, so far as one can judge from the literature of the subject, have proceeded upon the assumption that the amount of the illusory displacement is to be discovered by moving one end of the transversal vertically along the strip, the moving line to be kept always *parallel to itself*, until the point is reached where the two parts seem continuous. It would seem, however, that an unprejudiced approach to the problem should lead one to make room for any possible *angular* displacement that might be required to bring the moving end into a position of satisfactory apparent continuation with the fixed end. The writer recently constructed an apparatus which allows the determination of both vertical and rotatory displacement, but the meager results thus far obtained give no basis for any conclusion in the matter. Still the point seems well worthy of more extended attention.

3. *The Müller-Lyer Figure.*—Figure 5 presents in its typical form the much-discussed

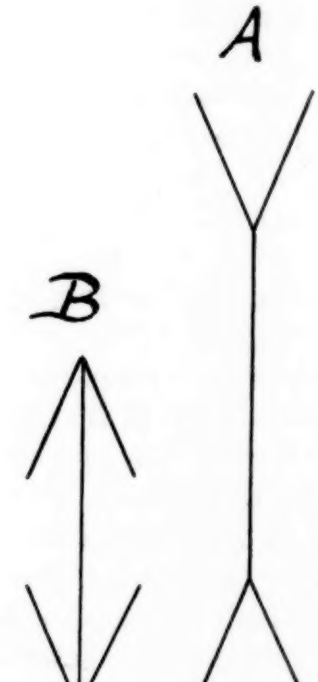

Fig. 5.

'optical paradox,' first published by Müller-Lyer in 1889, in the *Archiv für Physiologie.* No less than eight different explanations for this illusion have been propounded and warmly defended by the various writers. This number has been so far reduced by the reciprocal overthrow of the contesting parties that only three attempts at an explanation need detain us here. (*a*) The *perspective* theory is less fortunate here than usual.

According to it the principal line of A in the above figure is seen to be more distant from the observer than the principal line of B. The tiny obliques, that is, run forward from the point of contact in the former and backward in the latter. In consequence of this difference in apparent distance between the two lines, the dimensions of the figure must be apprehended in accordance with the universal law, that of two objects subtending the same visual angle that will be perceived as the greater which is projected to the greater distance from the eye. The perspective form, particularly of A, can be most easily seen where the ends of the obliques have been connected by straight lines; that is, when the whole figure has been enclosed in a rectangle. But now immediately the *equivocal* character of the figure becomes manifest. It may be seen, namely, either as an oblong hip-roof in miniature or as a hollowed out, crib-like object. In other words, the principal line may be made to appear now nearer, now more remote from the observer. Though less apparent, the same equivocal character is to be observed in the normal figure, B. But, whether nearer or more remote, *the apparent length of the principal line does not change*, and, since there are no compelling grounds to determine once and for all that A shall be seen in the distance and B in the foreground, the perspective explanation ignominiously fails, its whole structure being based, as we have seen, upon an *unequivocal* perspective reference.

The other theories mentioned are the 'confluxion-contrast' theory of Müller-Lyer, and the 'muscular energy' theory of Delbœuf and Wundt. (*b*) *Confluxion* is the term used to designate a class of facts where the estimated lengths of lines partake of the nature of the surrounding space in so far as this is indicated by other lines lying immediately adjacent. That is, the principal line of A is estimated as longer than that of B, because the total space inclosed by A is greater than that inclosed by B. Confluxion differs from contrast in that for the former any line *shares in* the characteristics of its surroundings, while for the latter any line assumes characteristics *opposite to* those of its surroundings. Here both motives are influential, confluxion as indicated, and contrast in so far as the principal line comes into comparison with the short obliques. This, in a word, is the 'confluxion-contrast' theory. Confluxion must evidently play the more important rôle in the present case. But an examination of this principle of explanation reveals the fact that its unreliability makes it very dangerous of acceptance. Cases can readily be found where, if true, the principle should be, but is not, effective. The most simple case is perhaps that given by Wundt (Fig. 6), where according to the

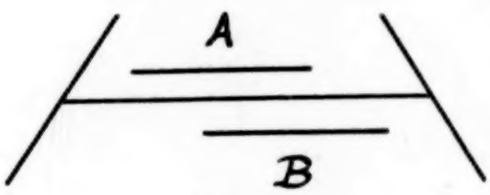

FIG. 6.

theory B *should* appear longer than A. Some further theory seems requisite, therefore, to satisfactorily account for the illusion.

(*c*) Though the forms given to the 'muscular energy' theory by Delbœuf and Wundt are by no means identical in respect to details, yet for purposes of description they may be brought together. Wundt has given by far the best statement of the theory. Its essence is that our visual spatial estimates are always influenced, if not first made possible at all, by the amount of energy expended by the muscles of the eye in running the point of regard over the figure viewed. The strength and range of this theory we can first see when later we examine the several principles of explanation. Meanwhile the statement will suffice that the tendencies to move the eyes beyond the

end of the principal line of A, and similar tendencies to fall short of the ends of the line in B, bring it about that the vertical of A is perceived as the longer. This will be true whether the eyes move freely along the line or remain fixated upon some point placed midway between the two figures lying side by side. In the latter case the illusion will be diminished in amount, though still existing, by reason of the fact that there can still be weakened impulses of the same kind as when the eyes are in motion.

A quantitative study of this illusion has shown that for each angle made by the two obliques a maximum of illusion is reached with a particular length of oblique, on either side of which the illusion diminishes. Thus, if the principal line be of 75 mm. and the angle between the obliques be 60 ° the maximum illusion occurs when the length of the oblique equals 30 mm.*

Innumerable forms can be given to the Müller-Lyer figures. The obliques may be replaced by fork-like ends with parallel prongs, or by circles and semicircles. Or A and B of Fig. 5 may be placed end to end in such a way that the outward pointing obliques of A become the inward pointing obliques of B, and in this condition various combinations of obliques may be omitted without destroying the illusion. Many more complex figures may be constructed which display illusions due to the presence of Müller-Lyer motives. Fig. 7 shows two of these, the side A appearing longer than that of B, though they are of equal length. Again, the point of bisection of the altitude of an isosceles triangle seems placed too high, the angle of the vertex acting apparently in the sense of B, of Fig. 5. Type founders have taken account of this in placing the horizontal of the letter A far below the middle.

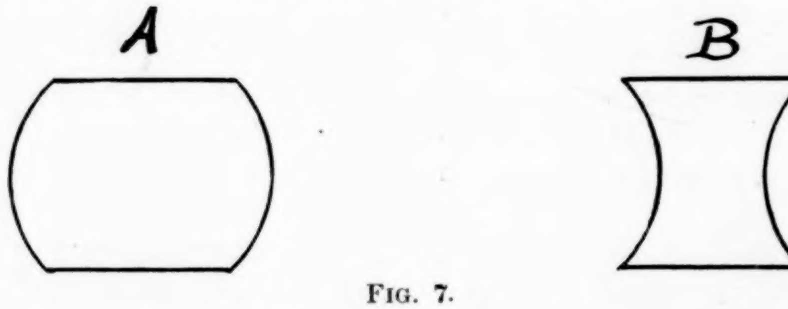

FIG. 7.

4. *Münsterberg's Illusion of the 'Shifted Checker-board Figure.'* The illusion of Fig. 8* differs essentially from all the foregoing, for while it resembles the Zöllner pattern in the converging and diverging character of the vertical lines its explanation rests upon a totally different principle, namely, that of *irradiation*. Fig. 8 may be called 'the illusion of the kindergarten patterns,' since it reproduces in black and white the type of patterns used in the occupation of mat-weaving. A single element of the illusion may be obtained by taking from the figure one of the vertical lines and the several pairs of overlapping rectangles that lie along it. If, further, the rectangles be changed to squares we have the form of the illusion first published by Professor Münsterberg only a few years ago in the Milton Bradley collection entitled 'Pseudoptics.' The brief assertion was there made that the illusion is due to irradiation. This statement, however, German writers have shown themselves singularly disinclined to adopt. Heymans† and Lipps‡

* Heymans. Zeitsch. f. Psych., etc., IX., 227.

* The illusion may be best seen by holding the diagram somewhat beyond the range of most distinct vision, or by viewing it as reflected in a mirror.

† Heymans. Loc. cit.

‡ Lipps. Op. cit., p. 319.

have brought it into relation with the Zöllner patterns and have made use of it to show that some other principle than the overestimation of acute angles must be employed in explaining the latter, since in the new variant no acute angles are present. Filelhne* has even attempted a perspective interpretation, according to which an element of the illusion, held horizontally, represents a bench, one end of which recedes into the background. As to the latter explanation, not only does it involve the arbitrary procedure of drawing additional lines to represent the seat of the bench, or of making the squares gradually smaller in order to suggest the greater distance of one end; but, more than all, it can give no satisfactory account of the illusion when the line of squares, or rectangles, lies vertically. There is, to be sure, a secondary illusion in the figure, to which several observers have called attention, which might lead one to suspect the presence of perspective elements. Hold Fig. 8 so that the plane of the paper makes a small angle with the line of vision. Then turn the diagram until the angle between the line of vision and the verticals equals about 30°. In this position the lines of rectangles that run away from the observer seem to form each a series of low steps. Running the eye along any vertical reveals this very clearly. The reason is evident. The background, as it were, for any rectangle viewed in this way is partly a white area, partly a similar black area. These areas are so distributed that when dark area is followed by dark area the middle portion of these joined areas must seem somewhat darker than the outlying parts, since the latter have received a grayish tinge from the white areas beyond. This darker portion can be interpreted only as a part lying in shadow, and hence the illusory perception of a low step, the 'riser' being the shadowed portion.

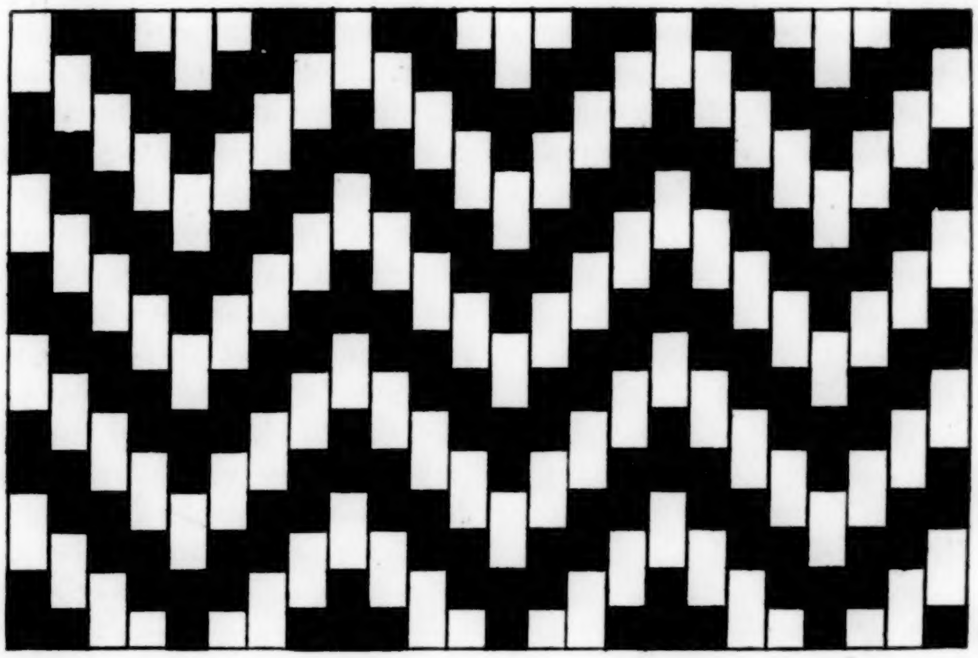

FIG. 8.

But as surely as this secondary illusion rests upon one of the accessory criteria of perspective vision, just as little can it furnish any basis for the perspective explanation of the primary illusion. That this is due to irradiation cannot now be doubted. The present writer endeavored recently* to

* Loc. cit, p. 42.

* *Psychological Review*, V. (1898), 233

show by a qualitative and quantitative study of this illusion that no factor other than irradiation need be appealed to for a thoroughly satisfactory explanation. The hesitation shown in accepting this explanation has been partly due, no doubt, to the fact that in the usual cases of encroachment by irradiation the diminished dark areas have retained outlines that are everywhere *parallel* to the original outlines of the figure. One has only to think of the dark square or circle on the light background. In the present case, however, the effective

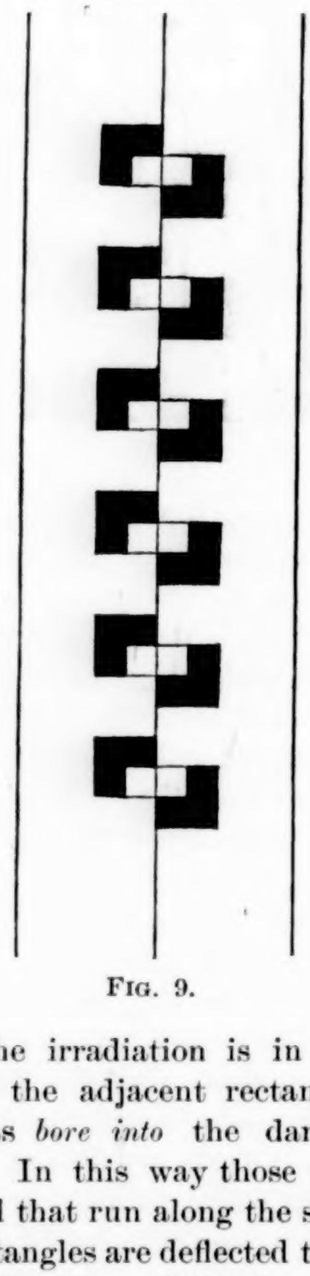

FIG. 9.

point of the irradiation is in the *corners* formed by the adjacent rectangles. The white areas *bore into* the dark corners, as it were. In this way those portions of any vertical that run along the sides of the various rectangles are deflected towards the corners, both above and below, and the deflections of these several portions give the tilted character to the line as a whole. This irradiation in corners is strikingly shown in Fig. 9, where the point of effective irradiation has been shifted to the centers of the incomplete squares. Here there is no longer a deflection of the vertical, but instead the bars of white that cross the line seem to slope slightly downwards to the right. The result of the qualitative and quantitative investigation above referred to showed clearly that the illusion vanishes whenever there can be secured the impossibility of irradiation in the corners situated along the line. The figures devised secured the latter condition while still retaining any factors that this figure may have in common with the Zöllner patterns. If, further, the character of the illusion in the regular figure was altered by substituting colors for the blacks and whites, or if the character of the illumination was changed by the use of the electric spark, or by the interposition of colored media between the diagram and the eye, the measurements of the illusion disclosed varying changes in the amount of apparent deflection. These results seemed to show the entire sufficiency of the explanation in terms of irradiation, at the same time rendering superfluous the appeal to, or the search for, any further explanatory principle.

5. *Loeb's Illusion.*—In 1895 Professor Loeb, of Chicago, called attention to the following interesting illusion.* Let M, Fig. 10, be a fixed vertical line and a a shorter line parallel with M and lying to the right. Placing M in the median plane and steadily fixating some point in it, place a second line b in such a position that it shall be continuous with a. This attempt will probably succeed very well. But now being a third line in the position occupied by c in the figure b will seem to lie too far to the right. That is, b must now be brought to

* Jacques Loeb. Pflüger's Archiv, LX., 516.

the position indicated in the figure in order to appear continuous with *a*. The lines employed may be narrow strips of black

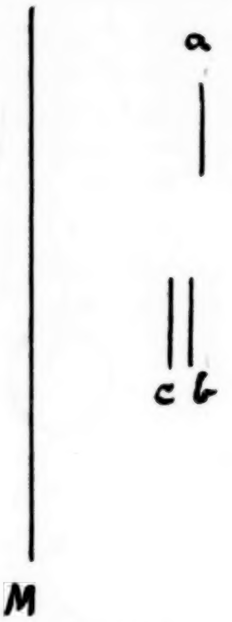

FIG. 10.

cardboard, or the lines may be replaced by coins or other objects of a similar nature. The discoverer's explanation is given in terms of *contrast*. If the space value of the impression *b* be the apparent distance of *b* from *M* we may say that this has been increased by the presence of *c*, since the resulting retinal impressions come now into the relation of 'contrast,' or of mutual repulsion, whereby the space value of *b* is increased. Accordingly *b* must be moved nearer to *M*, that its apparent space value may be equal to that of *a*. This explanation has not met with universal favor, and Heymans, Filehne and Wundt have each sought other solutions. The first attempts to unite this to the Zöllner illusion, the second to explain in terms of perspective. Wundt, in opposition to all previous attempts, points out the fact that this is an illusion of indirect vision, to be explained, therefore, only by reference to some known facts in that field. These facts he finds in the well known illusion of von Recklinghausen, in accordance with which rows of apparently horizontal and vertical points, placed farther and farther outwards from the point of fixation and in apparent parallelism with the real horizontal and vertical passing through this point, must be made to curve slightly with the convex side towards the point of fixation. In the illusion of Loeb *b* alone can be placed correctly in line with *a*, since the impression made by the lines is sufficiently strong to overcome the tendency to the Recklinghausen illusion. The addition of *c* restores the normal conditions somewhat, however, perhaps through the impression of imaginary lines drawn from *a* to *b* and *c*; and the expected inward inclination from *a* to *b* now takes place. That Wundt's explanation is wholly clear can by no means be asserted. Still, the full recognition of the fact that this is an illusion of indirect vision, and the attempt to subsume this under phenomena already known, are long steps towards a possible explanation that may prove more satisfactory.

6 *and* 7. *The Illusions of Baldwin and Judd.*—At the last meeting of the American Psychological Association, held during the Christmas holidays, two reports were made in reference to recently observed optical illusions. Professor Baldwin gave some new observations made upon the illusion of Fig. 11, with which the readers of SCIENCE were made acquainted through these colums in 1896. The point actually midway between the circumferences of the two circles seems nearer the larger. So far as the writer is aware, no final explanation has as yet been proposed. In the report referred to we are simply told that *perspective* 'has probably little influence,' and that the principle of 'equilibrium' cannot account for it, since the placing of the apparent middle point is in the contrary direction to that demanded by this principle. The announcement of further experimental results is awaited with interest. Dr. Judd has called attention to an interesting illu-

sion that seems to throw some light upon the general problem of visual space-perception. Two threads are so placed in a box that they cross each other at an acute angle while lying at different depths. If one of the points of crossing be properly fixated, two phantom threads will be seen passing between the main threads and making with each other a figure which, if viewed from the side, would resemble an X. The directions necessary for satisfactorily securing the proper conditions for this illusion are too detailed to find a place here. The interested reader is, accordingly, referred to the article designated in the foot-note.*

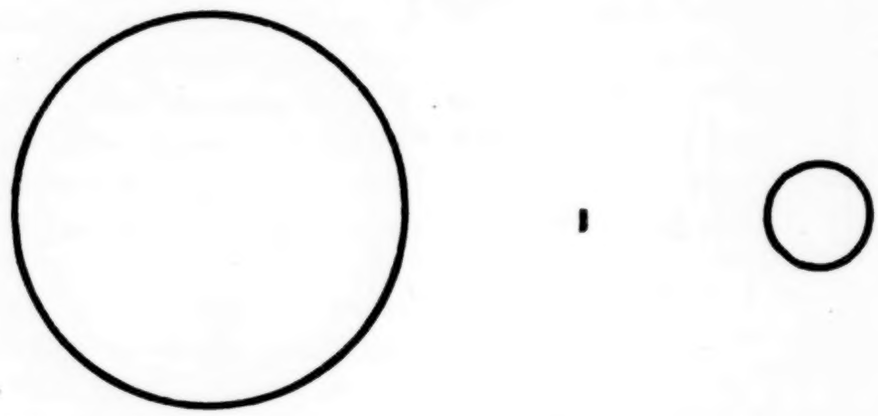

FIG. 11.

Such are the principal illusions that are being ardently discussed at the present time. To mention the numberless variants and minor illusions of form and magnitude that have come to light in the course of these discussions would be far beyond the scope of this article. The reader who cares to pursue the subject further is referred to the literature of the subject, particularly to Sanford's 'Laboratory Course in Psychology,' where may be found an excellent bibliography practically complete to the beginning of the current year.

B.

In attempting a brief summary of the discussions relative to the principles of explanation applied to optical illusions the following theories only will be considered: namely, the *contrast* theory, the *perspective* theory and the *physiological* theory. Lipps' æsthetic theory must remain unconsidered here, its unique form demanding rather a particular treatment by itself. Let us see how each of the three mentioned deals with the overestimation of acute angles. The *contrast* theory says that the two legs of an acute angle are in a relation of mutual antagonism, each point of one exerting a repelling influence, as it were, upon a point of the other. The consequence is, of course, that the whole angle appears larger than it really is. The *perspective* theory asserts that acute angles are not overestimated when unaccompanied with accessory lines formed by the prolongation of the legs of the angle, or otherwise. Then, and only then, the lines are regarded as *perpendicular* lines seen in perspective, and the acute angle gains therefrom an increment of magnitude. The *physiological* theory, by which that of Wundt is meant, claims that the relative magnitudes of angles depend upon the relative intensities of the muscular sensations gained by sweeping the eyes over the angle; and since for acute angles there is relatively more energy involved in the starting and stopping of the movements of the eyes, an acute angle, as compared with an obtuse, must be relatively overestimated.

*C. H. Judd, *Psych. Rev.*, V. (1898), 286.

As to *contrast*, the illustration here given does not exhaustively express the many phases under which this principle appears. Helmholtz has a theory of direction-contrast, Heymans one of movement-contrast, and Loeb one well illustrated by the case just treated. Since, however, no one of them contains in itself any reason for its particular way of working, it becomes in each case a mere name, a convenient expression only for the fact in hand. The only legitimate application of the principle of contrast is in those cases, well illustrated by the circles of Ebbinghaus (Fig. 12), where two objectively-equal areas become apparently diminished or enlarged respectively, according as they are brought into approximation with larger or smaller areas of the same nature. In this sense of the term the fact to which the principle is applied is brought into range with a multitude of facts in every department of mental life, the general law of which is that when any mental state with certain prominent characteristics is brought into comparison with a second state of opposite characteristics the peculiar quality of each is intensified, just as a season of joy is more joyful when immediately following a season of pain.

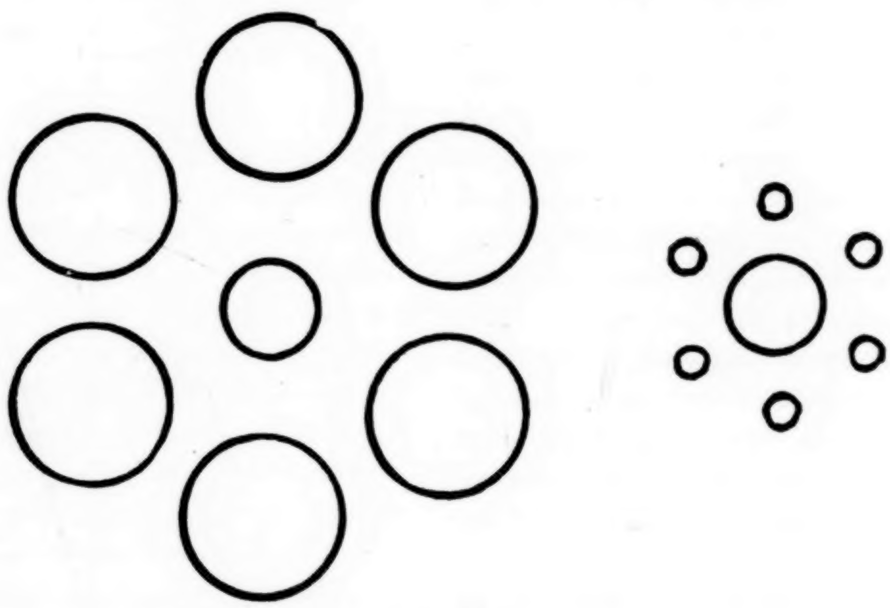

FIG. 12.

In the monograph already referred to more than once Wundt powerfully emphasizes the fact that the principle problem of *perspective* is to determine whether its position is primary or secondary; whether, that is, it is the *cause* of the illusion in a given case or the *effect* of an already present illusion. To determine this figures are found with no accompanying perspective phenomena, though the nature of the illusion is analogous to that presented by figures *with* perspective phenomena. It would seem, therefore, that perspective were wholly *secondary* to some more fundamental factor. And this presumption is strongly fortified by the fact that the perspective phenomenon is always *unequivocal*, that is, that dimension perceived as greater is always projected to the greater distance, and cannot by any effort of 'imagination' or 'will' be brought nearer. These few words give but a faint hint of the force of the argumentation in detail.

The *physiological* theory is the outcome of an attempt to discover some principle that shall be fundamental and hence capable of universal application—valid, that is, not only for 'variable' illusions of magnitude and direction, but also for such 'constant' illu-

sion as the overestimation of the upper half of a vertical. Such a theory Wundt long ago propounded. His recent work is only an especially thoroughgoing attempt, from a novel standpoint, to defend the old thesis. Especial emphasis is placed upon the consideration of equivocal figures and upon the secondary character of 'perspective.' And everywhere attention is called to the effect of particular positions and movements of the eyes. The essence of the theory is that every visual spatial perception is a complex formed by the assimilation of visual qualities with sensations coming from the muscles of the eye. Whatever, therefore, increases the intensity of the muscular sensations that enter into the complex occasions the perception of a greater spatial magnitude. The particular conditions necessary for this increase of muscular intensity are to be found both in the assymmetry of the eye-muscles and in those cases to which the general mechanical principle can be applied, that brief movements require relatively more energy than those of longer duration, since it is harder to start and stop a movement than to maintain one already under way. This theory is called 'physiological,' to call attention to the fact that the conditioning factors are of physiological rather than psychological origin. With the exception of a few cases, such as the illusion of contrast shown in Fig. 12, this principle of muscular energy finds universal applicability. One may be unwilling to accept the wide-reaching implications that this theory has for the general doctrine of space perception. Yet one must frankly admire Wundt's masterly effort at unification and acknowledge the compelling power of his argumentation, especially as it appears in this new form.

In conclusion, attention may be called to the illusion of Fig. 13, in which the oblique line *ab* appears to curve slightly at its point of intersection with the vertical. The illusion is not marked, but it can usually be seen by all observers. For some it may be more distinct if the three figures be held

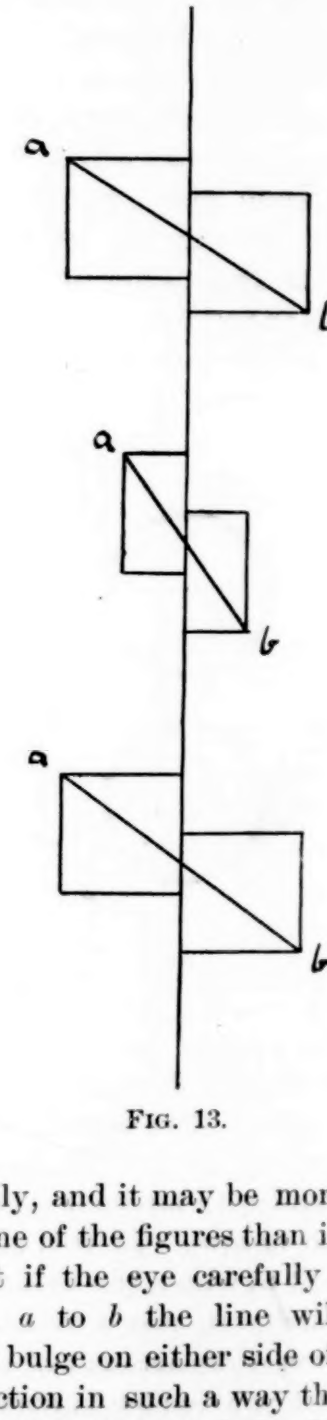

FIG. 13.

horizontally, and it may be more apparent in some one of the figures than in the other two. But if the eye carefully follow the line from *a* to *b* the line will probably be seen to bulge on either side of the point of intersection in such a way that it forms an extremely attenuated *S*. Each of the three principles of explanation considered above is applicable here. The first would say that the points of the oblique and the vertical are mutually antagonistic in the immediate vicinity of the point of intersec-

tion; the second, that perspective motives are operative in the neighborhood of the vertical, their further influence being prevented by the fact that the ends of the oblique are tied to the points *a* and *b*; the third, that the eye, in passing along the oblique, is solicited by the vertical, and the more resolute effort requisite to keep to the original path causes an apparent increase of the angle, the curving of the line being due to a conflict between the increase of the acute angles and the fixity of the outer ends of the oblique.

Which of these explanations shall we accept? A. H. PIERCE.

AMHERST COLLEGE.

SOME RECENT AND IMPORTANT EXPERIMENTS WITH THE EGGS OF THE SEA URCHIN.

THE well-known experiments of Boveri in which egg fragments were fertilized apparently gave evidence that the union of female cytoplasm with a spermatozoan may be followed by segmentation and development, but the proof is very inconclusive. It was left for Yves Delage to complete the evidence.

In a late communication to the French Acadamy* Delage states that he has succeeded in dividing the egg of *Strongylocentrotus lividus*, not *en masse* by shaking, as has been done heretofore, but by hand beneath the microscope and in such a way that there can be no doubt as to the fragments obtained being parts of the same egg. He was able to see that the nucleus was contained in one part and not in the other, which was, therefore, composed of ovulary cytoplasm. A whole or uninjured egg was placed beside the fragments and spermatozoa introduced into the drop of water in which the experiments were performed.

Sexual attraction manifested itself with equal energy by all objects. The controle egg and the two fragments were fecundated.

* *Comptes Rendus*, CXXVII., 15 pp., 528-31.

A little later segmentation began, appearing first in the controle, a little later in the nucleated and still later in the nonnucleated fragment. The rapidity of segmentation was greatest in the controle and least in the nonnucleated, so that when controle was in the stage 8 or 16 the nucleated fragment had developed to stage 4 and the nonnucleated to stage 2. In the drop of water the development could not be of long duration, but in one case it was successfully carried through three days. At the end of this time the controle formed a typical gastrula. The nucleated fragment had developed so that the only difference apparent was its smaller size. The nonnucleated fragment also developed into a gastrula, but with the enteric and blastocœlic cavities very much reduced, owing, no doubt, to the smaller size of the fragment. In all cases a vitelline membrane appeared about the blastomeres. Some of the larvæ were fixed and stained, and the nuclei and nucleoli found in the cells from the nonnucleated to be no smaller than those in the cells from the nucleated fragment.

From these experiments Delage deduces the following very important conclusions:

1. The ordinary definition of fecundation must be rejected as being too strict. The union of the female and the male pronuclei certainly takes place, but it is not essential to development.

2. Fol's conclusions as to the union of the two pronunclei and of the demi-ovocenters with the demi-spermocenters must be cast aside. For, as the experiments show, the absence of an ovocenter is not an obstacle to development.

3. The theories in which fecundation is explained as the saturation of a female nuclear polarity by a male nuclear polarity must likewise be dismissed, and also those theories regarding the formation of the polar gobules as for the purpose of ridding the female nucleus of all male elements.

4. It is likewise necessary to reject the theories in which the male element is regarded as supplying the chromosomes subtracted in the formation of the polar globules. In giving up part of its nuclear matter the egg does not become *ipso facto* incapable of ulterior development, since an ovulary cytoplasm provided with a number of chromosomes and a mass of chromatin equal to that which it had originally, but of paternal origin, is capable of forming an embryo.

5. Sexual attraction is not confined to the nucleus.

6. In fecundation there are two things to be considered: (*a*) The communication to the egg of a vital energy that permits it to segment and develop. (*b*) The communication to the product of advantages resulting from amphimixy and from the possession of hereditary characters.

On the second of these two questions no light is thrown by the experiments, but on the first there is, showing that the theories of fecundation reconcilable with it are those representing this phenomenon as the bearing by the male element of special energetic plasma (*kinoplasma*) contained in its sperm center.

7. There is no specific structure in the ovulary cytoplasm, the conservation of which is a condition of development. If a structure exists it is conditioned by mutual reactions of the parts and is capable of reestablishing itself when it has been altered.

8. Boveri's celebrated experiments, so warmly contested by Seeliger, are confirmed by the removal of the most serious objection to their validity, namely, the impossibility of cytoplasmic development without a nucleus. F. C. Kenyon.

AMERICAN ORNITHOLOGISTS' UNION.

The Sixteenth Congress of the American Ornithologists' Union convened in Washington, D. C., on Monday evening, November 14th. The business meeting was held at the Army Medical Museum. The public sessions, commencing Tuesday, November, 15th, and lasting three days, were held at the U. S. National Museum, the Central High School and the Cosmos Club.

Robert Ridgway, of Washington, D. C., was elected President; Dr. C. Hart Merriam, of Washington, D. C., and Charles B. Cory, of Boston, Vice-Presidents; John H. Sage, of Portland, Conn., Secretary; William Dutcher, of New York City, Treasurer; Charles F. Batchelder, Frank M. Chapman, Ruthven Deane, Drs. Jonathan Dwight, Jr., A. K. Fisher and L. Stejneger, and Mr. Witmer Stone, members of the Council. By a provision of the by-laws, the ex-Presidents of the Union, Drs. J. A. Allen and Elliott Coues, and Messrs. William Brewster and D. G. Elliot, are *ex-officio* members of the Council.

One active, one corresponding and one hundred and one associate members were elected—the largest number in any one year except one since the Union was founded. As in the previous year, a large percentage of the new associate members were women, a direct result of the Audubon Society movement, and of the present interest taken in the study of birds by the teachers in the public schools.

Mr. Witmer Stone's paper on 'Some early Philadelphia Collectors and Collections' was of special value from a historical point of view. New facts regarding Peale's Museum, Audubon, John Cassin and the early workers in ornithology in this country were given.

Wednesday afternoon and evening were devoted to papers illustrated with lantern slides. Through the kindness of Professor W. B. Powell, Superintendent of Schools of Washington, a hall at the Central High School was placed at the disposal of the Union and its friends for the afternoon. The first communication was by Mr. Frank

M. Chapman entitled 'The Bird Rocks of the Gulf of St. Lawrence.' He was followed by Dr. Thomas S. Roberts, who gave an exhibition of lantern slides of birds, birds' nests and nesting haunts from photographs taken by himself in Minnesota. Other slides were shown by Messrs. William Dutcher and William L. Baily.

In the evening the Union met in the Assembly Hall of the Cosmos Club, by courtesy of that Club. Here three papers were read, viz.: 'On the Nesting Habits of the Brown Pelican on Pelican Island, Florida,' by Frank M. Chapman; 'Chapter in the Life of the Canada Jay,' by Oscar Bird Warren; and 'Clarke's Crows and Oregon Jays on Mt. Hood,' by Florence A. Merriam. All of the slides exhibited were effective, showing care and patience in obtaining the negatives.

Mr. Witmer Stone, Chairman of the Committee on Protection of North American Birds, read a most interesting report on the work done during the past year. The report will be published in *The Auk*, and reprinted as a separate pamphlet, to be sold at a very low price.

The graphophone demonstration of a brown thrasher's song by Dr. Sylvester D. Judd was a new and unique feature of the Congress. Dr. Judd's experiments were made with a cage bird, but the results obtained were enough to show that great possibilities in this field may be looked for in the future.

Following is a list of the papers read at the session, in addition to those already mentioned:

'Among the Birds in Nevada,' Harry C. Oberholser.

'The Geographical Distribution of the Wrens of the *bewickii* Group,' Harry C. Oberholser.

'The Moult of Passerine Species in the vicinity of New York City,' Jonathan Dwight, Jr.

'The Nocturnal Flight of Migrating Birds,' O. G. Libby.

'The Distribution and Relationships of *Ammodramus maritimus* and its allies,' Frank M. Chapman.

'Chadbourne on Individual Dichromatism in *Megascops asio*, with some evidence on the question,' William Palmer.

'The Prothonotary Warbler, *Protonotaria citrea*, a common summer resident of Southeastern Minnesota,' Thomas S. Roberts.

'Polygamy among Oscines,' F. E. L. Beal.

'Crow Roosts in Eastern Pennsylvania and New Jersey,' Witmer Stone.

'Some Parasites of Birds,' by title, Vernon L. Kellogg.

'Some Characteristics of Neossoptiles,' William Palmer.

'The Generic Names *Pediocætes* and *Poocætes*,' Theo. Gill.

'The Blue Honey-creepers of Tropical America,' Harry C. Oberholser.

'The Water Ouzel on Mt. Shasta,' Florence A. Merriam.

The next meeting will be held in Philadelphia, commencing November 13, 1899.

JOHN H. SAGE,
Secretary.

CURRENT NOTES ON ANTHROPOLOGY.

THE MAP OF CUAUHTLANZINCO.

UNDER the above name Mexican archæologists have described a series of paintings about thirty-three in number, preserved in the native town bearing the appellation. They were drawn and colored some decades after the Conquest, in order to preserve the memory of that portion of it in which the town was engaged. In the present century a new copy was made, as the first canvasses were falling to pieces. Inscriptions in Nahuatl and Spanish were added, to explain the various scenes depicted by the native artists.

Professor Frederick Starr visited the hamlet in 1895 and again last January, and obtained photographs of all the pictures and a copy of the Spanish explanations. These he has published in an instructive monograph, issued from the press of the University of Chicago. It will be read with pleasure by those interested in the archæology of Mexico ('The Mapa de Cuauhtlantzinco or Códice Campos').

THE VARIATIONS OF THE MUSCLES IN MAN.

THE racial variations in the soft parts of the human frame is a much more difficult study than that which limits itself to the bony skeleton. For that reason anthropologists will welcome the publication of the results obtained by the late Dr. H. Chudzinski, who for twenty years occupied himself with such investigations. They are in part contained in a volume of 226 pages, edited by the eminent anatomist, Dr. L. Manouvrier, and published by the Anthropological Society of Paris. The comparisons are most complete between the white and black races, as of those, Dr. Chudzinski could, in Paris, secure good specimens. As for the 'yellow race,' in which he included a Carib, a Peruvian, a black from Pondichery and two natives of Farther India, evidently little value can be assigned its peculiarities, as based on such examples. (*Variations musculaires dans les races humaines*, Paris, Masson et Cie, 1898.)

PASSAMAQUODDY LITERATURE.

PREVIOUSLY in these notes (SCIENCE, May 13, 1898) I have referred to Professor J. D. Prince's interesting studies in the Passamaquoddy dialect. He has supplemented those by an article in the *Annals* of the New York Academy of Sciences (Vol. XI., No. 15), giving, from pure native sources, an outline of Wabanaki history previous to the establishment of the intertribal *modus vivendi* set forth in the 'Wampum laws.' The account illustrates the primitive condition of murderous warfare which prevailed, and the efforts of the wiser heads of the hordes to put a stop to such destructive excesses.

The paper ends with a Passamaquoddy love song which is presented in the original, with an English translation, and explanatory notes of the text.

D. G. BRINTON.

UNIVERSITY OF PENNSYLVANIA.

SCIENTIFIC NOTES AND NEWS.

WE are now able to give some further details in regard to the meeting of the American Society of Naturalists, and of the Societies holding their meetings in New York City in conjunction with it. The first meeting of the Society of Naturalists will be in the American Museum of Natural History on the evening of Wednesday, December 28th. After a welcome by the President of the Museum, Mr. Morris K. Jesup, Professor Henry F. Osborn will give a lecture on 'Collections of Fossil Mammals and their Care,' and will afterwards receive the members of the Societies at his house. The chief meeting of the Naturalists will be held on the afternoon of December 29th at Schermerhorn Hall, Columbia University. After the Societies have been welcomed by President Low a series of short papers will be read on 'Advances in Methods of Teaching' as follows:

Zoology: Professor E. G. Conklin, University of Pennsylvania.

Anatomy: Professor George S. Huntington, Columbia University.

Physiology: Professor W. T. Porter, Harvard Medical School.

Psychology: Professor Hugo Münsterberg, Harvard University.

Anthropology: Dr. Franz Boas, Columbia University.

Botany: Professor W. F. Ganong, Smith College.

The annual dinner will be held at the Hotel Savoy, and after the dinner the President of the Society, Professor Bowditch, will make an address. Visits to the Botanical and Zoological Parks have been arranged for December 30th.

THE other Societies holding scientific sessions simultaneously with the Naturalists open their meetings on Wednesday, except the Anthropologists of the American Association, who begin on Tuesday. Announcements of these meetings have been or will be sent out by the Secretaries to members, and further information can be obtained from them. The addresses of the several Secretaries are as follows:

Dr. H. C. Bumpus, Brown University, Providence, Secretary of the The American Society of Naturalists.

Dr. G. H. Parker, 6 Avon Place, Cambridge, Mass., Secretary of The American Morphological Society.

Dr. D. S. Lamb, 800 Tenth Street, N. W., Wash-

ington, D. C., Secretary of The Association of American Anatomists.

Dr. F. S. Lee, Columbia University, New York City, Secretary of The American Physiological Society.

Dr. Livingston Farrand, Columbia University, New York City, Secretary of the American Psychological Association.

Mr. W. W. Newell, Cambridge, Mass., Secretary of The American Folk-Lore Society.

Dr. W. F. Ganong, Smith College, Northampton, Mass., Secretary of the Society for Plant Morphology and Physiology.

Dr. H. M. Saville, American Museum of Natural History, New York, Secretary of Section H (Anthropology) of the American Association for the Advancement of Science.

PROFESSOR WILLIAM TRELEASE, Director of the Missouri Botanical Garden, and Mrs. Zelia Nuttall have been elected honorary members of the Sociedad Scientifica (Antonio Alzate), of Mexico.

M. LEVY, the mining engineer, Paris, and Professor Lindström, Director of the Natural History Museum of Stockholm, have been elected corresponding members of the Berlin Academy of Sciences.

THE Munich Academy of Sciences has elected the following members: Professor Fuchs, of Berlin (mathematics); Professor Barrais, of Lille (geology); Professor Lie, of Christiania (mathematics); Professor Hartig, of Munich (botany); Professor Pringsheim, of Munich (mathematics), and Professor Oberhummer, of Munich (geography).

PROFESSOR G. FREDERICK WRIGHT, of Oberlin College, has made plans for a trip around the world in 1900, for the purpose of studying geological phenomena. He will visit Hawaii, Japan, cross Asia, following the line of the new Siberian railroad, studying especially the Siberian glacial drift, a field as yet untouched; thence, after a study of the region around the Caspian Sea, he will return to the United States, the whole trip occupying about nine months.

PROFESSOR JAMES E. KEELER, the recently appointed Director of the Lick Observatory, was given a reception and banquet on October 15th, at San Francisco, by the members of the faculties of the University of California. There were about sixty present. Addresses of welcome were made by the President of the University and Professor Soulé, and Professor Keeler replied.

DR. WILLIAM C. KRAUSS, of Buffalo, N. Y., has been elected President of the American Microscopical Society.

A FURTHER grant of £250 has been made from the Worts Travelling Scholars' Fund of Cambridge University to Dr. Haddon, towards defraying the expenses of the scientific expedition to the Torres Straits under his direction for the purpose of making anthropological investigations.

THE French Institute announces as the subject of the Crouzet prize (3,000 fr.) for 1901, 'The Theory of Evolution in Nature and in History.'

THE French Geographical Society held a special session on November 19th in honor of the explorer M. Gentil. M. Milne-Edwards, who presided, after congratulating M. Gentil on his remarkable explorations in the neighborhood of Lake Tchad, announced that the Society had awarded to him its large gold medal for the year 1899.

THE monument erected to Charcot, the great French neurologist, before the Saltpêtrière Hospital, Paris, was unveiled on December 4th. M. Leygues, the Minister of Public Instruction, made an address.

SIR GEORGE STOKES was elected Lucasian professor of mathematics at Cambridge on October 28, 1849, and the current academical year is thus the 50th year of his tenure of the chair. The Council of the University, having regard to the acknowledged eminence of Sir George Stokes and to the rarity of such an event as a 50 years' tenure of a professorship in the University, are of opinion that some formal celebration of the completion of this period should be held towards the end of the present academic year, and that a number of distinguished men of science, and also representatives of universities and other learned bodies at home and abroad, should be invited to participate in the celebration. They have considered various dates that are suitable for the celebration, and

have come to the conclusion that June 1 and 2, 1899, will be the most convenient. The Council recommend that a sum of £400 be placed at their disposal for the celebration.

Mr. Richard Bannister, late Deputy-Principal of the Government Laboratory, says the London *Times*, was presented, on November 21st, in the hall of the Civil Service Volunteers at Somerset House, with a testimonial which had been subscribed for by his colleagues and friends in the department from which he has recently retired after a service of 42 years. In making the presentation Dr. Thorpe, F.R.S., the Principal Government Chemist, after referrring to Mr. Bannister's long and varied experience in the Government Laboratory, spoke of his work outside the department, with which the public were perhaps better acquainted. His administration of the Food and Drugs Act and his numerous appearances before Royal Commissions and Parliamentary Committees, as well as his selection as a juror at several of the South Kensington Exhibitions, were evidences of the value in which his vast and unrivalled experience, not only in chemistry, but in the trading and comercial interests connected with it, were held. Mr. Steele, late Chief Inspector of Excise, and others also bore witness to the value of Mr. Bannister's services both to the department and the public generally.

The death is announced of Professor George T. Allman, F.R.S. He was born in Ireland in 1812, and was appointed professor of botany in Dublin in 1844. In 1855 he was called to Edinburgh, and was there professor of natural history till 1870. He described the hydroids collected by the Challenger Expedition, and published a number o monographs treating of the invertebrates.

We regret also to announce the deaths of M. J. N. Raffard, a French inventor; of Herr A. Hubner, the historian, General Secretary of the Vienna Academy of Science, and of Sir George Baden-Powell, who has in many ways promoted scientific undertakings in Great Brittain.

A Civil Service examination will be held on December 15th for the position of Assistant in Entomology, Office of Experiment Stations (Department of Agriculture). The examination will consist of the subjects mentioned below, which will be weighed as follows:

Biology and entomology	50
French or German (translation of scientific literature)	10
Editing and abstracting	10
Essay	15
Training and experience	5
Additional modern languages, or veterinary science	10
Total	100

Lieutenant A. P. Hayne, an instructor in the agricultural department of the University of California, now stationed with one of the California regiments at Manila, has been detailed to conduct an official investigation into the agricultural resources of the Philippines, and to make a report of the results to Washington.

The Secretary of State has received a cable message from United States Consul Gibbs at Tamatave, Madagascar, saying that the bubonic plague has broken out at that place.

The Valentine Museum at Richmond, Va., was formally opened to the public on November 21st. It is a gift to Richmond by the late Mann S. Valentine, and includes, housed in his recent mansion, his valuable collection of books, oil-paintings, manuscripts and casts, supplemented by scientific collections of anthropological specimens. The will of Mr. Valentine expresses his desire that the Museum be closely associated with and an aid to the educational institutions of the State; that it publish literary and scientific papers and preserve objects of antiquity compatible with the amount of endowment of the Museum.

The University of Michigan Museum has been enriched by a gift of the collection of musical instruments brought together by Frederick Stearns. In presenting this collection, of nearly 1,000 pieces, Mr. Stearns turned over the results of fifteen years' research and over $25,000 expenditure. The present value of the collection is much greater than its original cost. Among other things, it illustrates the evolution of several musical instruments from primitive times down to the present.

THE New York State College of Forestry has secured its 30,000-acre demonstration area of Adirondack forest. The terms of sale are agreed on, and only a survey delays the formal turning over of the property. The tract lies in Franklin county, to the south of Saranac Lake, and partly upon the lower slope of Mt. Seward. It contains some virgin forest, some from which lumbermen have taken the choice timber, and some from which forest fires have taken all the timber. The College can, therefore, at the start demonstrate all sides of forestry, from planting bare tracts to lumbering and getting the logs to market.

THE Ludwig Institute courses of free lectures are now being given on the evenings of Mondays and Thursdays at the Philadelphia Academy of Natural Sciences. Dr. Edward J. Nolan has given two lectures on the literature of natural history. Mr. Witmer Stone and Professor Henry A. Pillsbury are at present giving courses respectively on vertebrate zoology and on the oyster and the clam. After Christmas Dr. Benjamin Sharp will give a course on comparative anatomy and physiology, Dr. Henry Skinner a course on entomology, Mr. Stewardson Brown a course on botany and Dr. Seneca Egbert a course on hygiene.

A CABLEGRAM to the New York *Evening Post* states that Mr. George Murray's deep-sea expedition, to the plans of which we recently referred, has completed its work in the North Atlantic. Its main object was to obtain further information regarding the vertical range of life in the sea, especially to test Professor Agassiz's theory that the intermediate depths of ocean are uninhabited, life being confined to the uppermost 500 fathoms and the lowest 100 fathoms. Depths of 1,370 and 1,835 fathoms were reached, samples of typical globigerina ooze being brought up from the latter. The full bearing of the results of the expedition must await many months of sorting and cataloguing of collections, but the general impression of the members of the expedition is that the Agassiz theory will not be maintained.

A SPECIAL despatch from Yeniseisk, on the river Yenissi, in eastern Siberia, announces the arrival at the mouth of the river of an expedition that had gone in search of Herr Andrée, the aeronaut. The expedition was wrecked while crossing from the delta of the river Lena to the river Olenek, which flows into the Arctic Ocean southwest of Bennett and Delong Island, but managed to reach an uninhabited island about 120 miles from the mouth of the Olenek. The party was ice-bound for seventeen days before it was succored.

M. THIBEAUT, Chargé d'Affaires of France, has notified Secretary Hay that the French government is about to adopt precautionary measures against the introduction from this country of the San José scale, and that decrees will be issued prohibiting the importation of trees, shrubs and plants from the United States and requiring an inspection of all fruits, fresh and dried, at the point of landing in France.

UNIVERSITY AND EDUCATIONAL NEWS.

THE Lawrence Scientific School, Harvard University, has received $10,000 from Mr. J. H. Jennings, of the class of '77, for the establishment of a scholarship. The scholarship for the current year goes to Mr. T. F. Sanborn.

JAMES STILLMAN, of New York, has given $50,000 to Harvard College to cover the cost of land and buildings for a projected Harvard Infirmary, which will bear the name of the donor. In addition, Mr. Stillman will contribute $2,500 annually for four years.

THE will of the late Charles P. Wilder, of Wellesley Hills, bequeathes $102,000 to Mount Holyoke College, and the trustees of Wellesley College announce a gift of $50,000 made by Mr. Wilder before his death. No conditions are attached to the gift.

THE Catholic University of Washington has received the information that by the will of Daniel T. Leahy, of Brooklyn, it receives $10,000. No instructions accompany the bequest.

WE have been able to record recently two important gifts to the University of Cincinnati, including the gift of a library building by Mr. Asa Van Wormer. The University has now been presented by Mr. William A. Proctor with the library of Mr. Robert Clarke, containing 6,704 volumes valued at over $50,000.

A FUND of $100,000 is being raised by the trustees and friends of Oberlin, the income from which is to be applied to the reduction of the term bills of needy students. About one tenth of this amount has already been collected.

THE Commission appointed under the University of London Act, 1898, consisting of Lord Davey (Chairman), the Bishop of London, Sir William Roberts, Sir Owen Roberts, Professor Jebb, Professor Michael Foster and Mr. E. H. Busk, with Mr. Bailey Saunders as Secretary, has commenced its sittings.

THE Montreal correspondent of the New York *Evening Post* states that according to present arrangements the formal opening of the new chemistry and mining building at McGill University will take place on December 20th. There is a possibility, however, that an earlier date may be selected in order to meet the convenience of Lord Strathcona, who wishes to be in Scotland for Christmas day. The Governor-General and the Countess of Minto will be present. The authorities of McGill University have been notified of the loss of between $3,000 and $4,000 worth of chemical apparatus intended for the new chemical laboratories at the University. The goods were shipped by the ill fated Westmeath, which was lost at sea a short time ago.

DR. JOHN HENRY BARROWS has been elected to the Presidency of Oberlin College. This action was taken by the trustees of Oberlin on Tuesday, November 29th, and the vote was unanimous. Dr. Barrows is widely known as the pastor of the First Presbyterian Church of Chicago, and as the one who pushed the Parliament of Religions at the World's Fair through to its successful end. During the last two years he has been lecturing in Calcutta, India, on the Haskell lectureship of the University of Chicago. Definite word has not yet been received as to his acceptance, but the trustees had assurance that he would accept, before the action was taken.

THE Normal College, New York City, has adopted courses of study by which the students may receive academic degrees. The members of the faculties concerned with the sciences are as follows: Professor Joseph A. Gilette, analytical geometry; Professor Burgess, biology and geology; Emily I. Conant, Ph.D., psychology, and Isabel Camp, Ph.D., pedagogics.

THE Council of King's College, London, have appointed Mr. Ernest Wilson, M.I.E.E., professor of electrical engineering in succession to the late Professor Hopkinson.

DISCUSSION AND CORRESPONDENCE.

A SELF-READJUSTING 'COHERER.'

TO THE EDITOR OF SCIENCE: Van Gulik has shown [Wied. Ann., No. 9.] that, when an oscillating electric discharge takes place across a minute gap between the ends of two fine platinum wires, the ends of the wires are drawn together and remain clinging together after the discharge has ceased.

Upon repeating some of his experiments in a modified form, I am led to the conclusion that such adherence does not always result if the gap be between dissimilar metals.

Advantage may be taken of this to construct a self-readjusting 'coherer.' If a Branly tube be filled with a mixture of tin and aluminium filings it acts normally in so far that, when subjected to the influence of electric waves, its resistance is greatly diminished. When the radiation has ceased, however, its resistance again rises, unaided by any tapping back. A similar result obtains, though the reaction is usually more sluggish, with a pile of alternate disks of aluminium and tin foil.

A. E. LAWRENCE.

COLUMBIA UNIVERSITY,
November 19, 1898.

ADDITIONAL NOTES ON AN APPLE CANKER.

FROM observations made since the publication of the article 'An Apple Canker' in SCIENCE for October 28, 1898, it seems highly probable that *Sphæropsis malorum*, Peck, is not only parasitic on the wood of the apple, but on the wood of pear and quince as well. It would, therefore, seem that a further note on the subject will not be out of place.

In the spring of 1898 specimens of blighted apple twigs were received. It was not determined at the time what was the cause of the

blight, but later the surface of the bark was found to be thickly dotted with the pycnidia of *Sphæropsis*.

On visiting the orchard, which comprised about five acres, it was found that the blight had been quite noticeable in 1897. In all cases noticed when once attacked the entire growth of the season had been killed, and in a few instances the disease had extended into the previous season's growth. The dead twigs varied from a few inches to a foot or more in length. But few twigs of the current season's growth were found to be attacked. The growth of the disease on the twigs is determinate, a definite constriction usually separating the dead from the living wood. A few miniature canker spots were found on the smaller limbs, but none were noticed on the larger limbs, as is usually the case. The trees were generally in good condition, and the black rot of the fruit was not specially abundant.

Some pear trees in a door yard about twenty-five rods distant from the orchard were found to be dying. The top of one tree had been entirely removed, while the other trees were a half or two-thirds dead. These trees were also found to be attacked by a *Sphæropsis*, the pycnidia being very abundant on the dead bark. The spread of the disease was from the top downward, a distinct boundary separating the dead from the living wood. A few black shrivelled pears were still attached to some of the dead branches.

A *Sphæropsis* was also found on the twigs of some quince trees that grew by the side of the pear trees. The injury in this case was slight.

At a later date a canker was found on some quince trees in the Experiment Station orchard. Here the appearance of the cankers and their effect was much the same as on apple trees. Pycnidia of a *Sphæropsis* were abundant where the fungus was in active growth. The disease was also found to be abundant in a large qunice orchard, in the vicinity of Geneva, where it has done a considerable amount of damage.

Cultures of the *Sphæropsis* were made from the twigs of the three different host plants, and fruits of the apple, pear and quince were inoculated with material from each of the three series of cultures. *Sphæropsis malorum*, Peck, was produced in each case, while check fruits, punctured but not inoculated, remained sound.

GENEVA, N. Y. W. PADDOCK.

SCIENTIFIC LITERATURE.

Lehrbuch der anorganischen Chemie. Von PROFESSOR DR. H. ERDMANN in Halle, mit 276 Abbildungen und vier farbigen Tafeln. Braunschweig, Vieweg. 1898. Pp. 756.

Professor Erdmann has taken the Gorup-Besanez text-book (1876) as a foundation, but has so changed, improved and modernized the work that it may fairly be considered entirely new.

The printing and illustrations are admirable; particular attention is called to the beautiful colored plates of the spectra of various elements, including argon and helium, which show a wonderful delicacy of tone.

In an introduction of eighty pages the author discusses chemical theory, temperature, gases, atomic and molecular weights, and similar topics. The remainder of the book is chiefly descriptive, yet modern theory is introduced when needed. The striking features of the book are its thoroughness, its completeness, and the particular attention given to technical methods, preparation and experiment. As to thoroughness and completeness the reviewer has not succeeded in detecting the omission of a single fact of importance in inorganic chemistry, which could suitably find place in a book of the size and which was mentioned in chemical journals before 1898.

As to technical methods a few examples must suffice. It is generally known that much or most of the chlorine now made is by electrolysis of aqueous potassium chloride; but that chlorine is technically obtained as by product in the electrolysis of zinc from zinc chloride, magnesium from carnallite and sodium from salt, will be new to many, as will be the manufacture of hydrochloric acid on a large scale from magnesium chloride and steam: $MgCl_2 + H_2O = MgO + 2HCl$. If we turn to magnesium chloride we learn that, in addition to its use for hydrochloric acid and (as carnallite) for magnesium, 15,000–20,000 tons are yearly exported from Stassfurt to be used in cotton factories instead of oil, as concentrated magnesium

chloride solutions are oily to the touch and serve to make cotton thread pliable.

The reviewer does not wish to give the idea that this work is chiefly technical ; it is not ; it is a scientific text-book of the highest rank ; but the author notices briefly many important modern uses of common substances which are not known to the average teacher of chemistry, but should be known to the average advanced student. We find descriptions and drawings of apparatus for making argon, helium, liquid air (Linde), liquid oxygen (both Pictet and Cailletet) and fluorine (Moissan). Each chapter has an appendix on 'Technique and Experiments,' in which the best laboratory and lecture-room experiments are described with drawings ; the author's previous books on inorganic and organic preparations are guarantee that this part of the work is excellent.

One feature in the book calls for adverse criticism. No mention is made of relations between the atomic weights and properties of elements till the close of the book, where one page is given to relations like those existing between the atomic weights of the halogens, and two pages to the periodic system. No mention is made of the periodic law as a generally recognized law. The author says : "Mendelejeff has definitely stated that the properties of the elements are periodic functions of their atomic weights ;" and this is the only reference to such a law. This seems to the reviewer a serious blemish in a book otherwise so excellent. It may be that the author feels towards the periodic law as he Irishman felt towards government, but at east a fuller discussion of the subject is desirable. Surely the recognition given of late years to the 'family' relations of the elements, and the use of the periodic system throughout text-books, have been a great help to students. One misses this in the author's treatment of the halogens, for example ; yet the single halogens and their compounds are so well discussed, and the chapter on iodine is such a masterpiece, full of information, some of which will be new to most college professors, that it becomes hard to criticise anything so good.

This work is an excellent text-book for advanced college students ; it is an excellent book of reference for the lecturer and high-school teacher, and it should be carefully read by college professors.

E. R.

Lecture Notes on the Theory of Electrical Measurements. By WILLIAM A. ANTHONY. New York, John Wiley & Sons. Pp. 90.

This little volume is designed to furnish the student with the broad outlines of the subject treated, and to thus assist him in getting possession of the subject as more elaborately presented in a series of lectures. The fundamental equations upon which electrical measurements are based are given, and the physical conditions to which they apply are stated with clearness. The book opens with a short chapter on C.G.S. units. Then follow chapters on the magnetic field, current, potential and electromotive force and resistance, with a statement of Ohm's law. The international electrical units are then treated. The general plan of measuring resistance, current and potential is explained, the instruments used being represented in diagram. The second branch of the subject closes with a treatment of the methods of calibrating amperemeters, voltmeters, resistance sets and bridge wires. The remaining portion of the work, comprising sixteen pages, is devoted to the effects of the current in heating, glow and arc lighting, electrolysis and electro-magnetic induction. The electro-magnetic circuit is also discussed. The book is provided with an index and table of contents.

F. E. N.

The Mechanical Composition of Wind Deposits. By JOHAN AUGUST UDDEN. (Augustana Library Publications, No. 1.) Rock Island, Illinois. 1898. Large 8vo. Pp. 69.

Professor Udden has for some years been engaged in researches concerning the mechanical composition of the loess skirting Mississippi River, and has been led to a comparative study of the composition of other deposits, especially of eolic origin, and also to a highly-refined investigation of atmospheric dust ; and his principal results, with many of the details, are incorporated in this memoir. For convenience, he classifies wind-deposits in eleven grades, from coarse gravel (8–4 millimeters in diameter) to very fine dust ($\frac{1}{128}$–$\frac{1}{256}$ millimeters in diameter), and the examination was so conducted as

to ascertain the magnitude of the particles and the relative proportions of the different grades in terms of this scale. "Down to the particles measuring one-eighth of a millimeter all the separations were made by sieves, and below this the per cent of the weight of each grade was determined by microscopic measurements and by calculation from the number of grains counted in each grade" (page 6). Acknowledgment is made to Professor Milton Whitney for information concerning the mechanical analyses in the United States Department of Agriculture. The deposits examined include drifting sand, both rolled and dune, from Illinois, Indiana, Kansas, Nebraska, North Dakota and Massachusetts; and lee sand from Illinois, Kansas and North Dakota. In addition, special attention was given to atmospheric dust, formed and carried under various conditions, which was collected by ingenious devices. In the final pages the author discusses the principles of what may be called eolation, *i. e.*, eolic erosion (the deflation of Walther) and eolic deposition, and he refers to the bearing of the researches on the problem of the loess, though wisely withholds final judgment concerning the solution of the problem. The memoir carries inherent evidence of patient and painstaking labor; and, since the labor extended into a little-wrought but important field, it must take rank as a notable contribution to geology.

W J M.

SCIENTIFIC JOURNALS.

THE *American Journal of Science* for November contains the following articles:

'Another Episode in the History of Niagara Falls:' By J. W. Spencer. 'Apparatus for Measuring very High Pressures:' By A. deF. Palmer, Jr. 'Application of Iodine in the Analysis of Alkalies and Acids:' By C. F. Walker and David H. M. Gillespie. 'Associated Minerals of Rhodolite:' By W. E. Hinden and J. H. Pratt. 'Revision of the Moraines of Minnesota:' By J. E. Todd. 'Preliminary Report on some new marine Tertiary horizons discovered by Mr. J. B. Hatcher near Punta Arenas, Magellanes, Chile:' By A. E. Ortmann. 'Comparative Value of Different Kinds of Fossils in Determining Geological Age:' By O. C. Marsh. 'Families of Sauropodus l inosauria:' By O. C. Marsh. 'Biotite-tinguaite Dike from Manchester by the Sea, Essex County, Mass.:' By A. S. Eakle. 'Descriptions of new American Actinians with critical notes on other species, I.:' By A. E. Verrill.

THE *Journal of Comparative Neurology*, published quarterly at Granville, Ohio, and edited by President C. L. Herrick, Dr. O. S. Strong and Dr. C. Judson Herrick, has added to its collaborators Professor C. F. Hodge, of Clark University (Neurocytology, especially functional changes in nerve cells); Dr. G. H. Parker, Harvard University (The sense organs and nervous system of the invertebrates), and Professor A. D. Morrill, Hamilton College (The sense-organs of the vertebrates).

THE *Educational Review* for November opens with an article on the 'Status of the American Professor,' by 'One of Them.' The author urges that the American professor, with the exception of those in several of our larger universities, lacks a proper income, proper authority and proper leisure. Especial attention is called to the unfortunate fact that a college instructor can often only secure the advancement that is his due by securing a call from another university. The author might have added that the conditions are peculiarly bad in America, where an offer from a university is usually given privately and sometimes confidentially. In Germany a vacant position is usually offered to the man who is thought to be the best and who at the time holds a position that is considered less desirable, without regard to whether he is likely to accept or not. The German professors and docents have thus in their own subjects a rank depending on their reputation and efficiency, which is tolerably well known to the authorities of all the universities.

SOCIETIES AND ACADEMIES.

SECTION OF GEOLOGY AND MINERALOGY OF THE NEW YORK ACADEMY OF SCIENCES, OCTOBER 17, 1898.

THE first paper, by Professor J. F. Kemp, on the Minerals of the Copper Mines at Ducktown, Tenn., gave a brief history of the mines and described some of the processes employed in treating the ores, and the character of the rocks and associated minerals. The paper was illustrated with an extended series of lantern views

of the mines and the works, and with a suite of specimens. Professor Kemp referred particularly to the extremely interesting crystals of almandite garnet which he showed, in which the faces of the hexactahedron are strikingly developed, giving 48-sided forms, sometimes with small faces of the rhombic dodecahedron in addition. Zaisite also occurs in fine terminated crytals, and limonite of remarkable iridescence.

The second paper was by Dr. Arthur Hollick —Notes on the Glacial Phenomena of Staten Island—and embodied the general results of several years of study and exploration by himself and others. He outlined the topography of the island and the distribution of drift material upon it, and described the transported contents of the drift with relation to their sources. Most of the drift material is made up of the triassic sandstone and shale of the adjacent mainland, ground up by the ice sheet, but the boulders are largely brought from afar. They comprise material from all the fossiliferous beds of central New York, from the Potsdam to the Hamilton; but there is a great preponderance of Lower Helderberg and Schoharie grit. The fossils are in many cases finely preserved, have been collected in large quantities, and very carefully studied and determined. The question as to the route by which they have come, over the hilly and almost mountainous regions lying between their source and their resting place, is one of much interest.

The next paper was by Mr. Francis C. Nicholas—on the Sedimentary Formations of Northern South America—and dealt with a large area of little-explored country between the Caribbean coast and the northern Andes. It was illustrated by a most extensive and carefully labeled series of rocks, ores and minerals from many localities and horizons, to which it was impossible to do justice within the limits of the evening. Among many interesting points described and illustrated with specimens was the agency of the sun's heat as a rock-disintegrator, the changes of day and night temperature in high regions in the tropics producing a fracturing of the superficial portions of exposed rocks comparable in result to the action of frost in higher latitudes.

The last paper was by Mr. Geo. F. Kunz, upon a Meteoric Stone that fell at Andover, Maine, on August 5th last, with exhibition of the stone, or rather about half of it. The fall took place early in the morning of a cloudy and threatening day; so that the sound made by the meteor, which was heard for many miles around, was generally supposed to be thunder. A dark cloudy trail, like a dense smoke, followed and marked the path of the body through the air. Its course was from the north, southward, and in coming down it tore its way through a group of large trees, struck a heavy stone in a wall near the ground, and buried itself in the earth. Here it was found two days later, by that time entirely cooled. The specimen is a typical stony meteorite, with a thin black crust on the outside, and of a bright pale gray on the broken surface, with very little iron. It weighs about 7 lbs., and its description will appear later.

NEW BOOKS.

Instinct and Reason. HENRY RUTGERS MARSHALL. New York and London, The Macmillan Company. 1898. Pp. xiii + 574. $3.50.

Truth and Error. J. W. POWELL. Chicago, The Open Court Publishing Company. 1898. Pp. 428. $1.75.

Symbotæ Antillanæ seu fundamenta Floræ Indæ Occidentalis. IGNATIUS URBAN. Berlin, Borntraeger. 1898. Vol. I. Part I. Pp. 192. M. 10. 80 Pf.

Deutscher Botaniker Kalender für 1899. P. SYDOW. Berlin, Borntraeger. 1898. Pp. 198. M. 3.

Congrès national d'hygiène et de climatologie médicale de la Belgique et du Congo. Bruxelles, Hayez. 1898. 2d part. Pp. 247–890.

Traité élémentaire de méchanique chimique fondée sur la thermodynamique. P. DUHEM. Paris, A. Hermann. 1898. Vol. III. Pp. 380. 10 fr.

The Principles of Biology. HERBERT SPENCER. New York, D. Appleton & Co. 1898. Part I. Revised and Enlarged. Pp. xii + 706. $2.00.